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THE HAWAIIAN PLANTERS' RECORD

Early experimental evidence from Waipio Substation showing the value of fertilizer. Amounts of cane harvested from 1/30 acre plots: Top—No fertilizer. Bottom—1,130 pounds of nitrate of soda per acre.

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Weed Control on Hawaiian Sugar-Cane Lands —Contact Herbicides[1]

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The rapid progress of the past two years in chemical research devoted to the formulations of herbicides has embraced new materials and synthetic processes having outstanding weed-destructive properties.

The older contact herbicides used in Hawaii are gradually being replaced by modern and less hazardous preparations. One of these is Concentrated Activated Diesel Emulsion (CADE), the development of which this contribution attempts to describe.

The findings resulting from recent and current studies will appear in subsequent articles. This later work will cover both pre-emergence and contact developments employing 2,4-D and its derivatives, the oil-soluble H.S.P.A. Activator, aromatic petroleum by-products, and both oil and water-miscible concentrates designed for employment with modern spraying and nozzle equipment.

Luxuriant weed growth in cultivated soil is not seasonal in Hawaii. It is a troublesome factor with which the planter must contend at all seasons. Natural and artificial irrigation, the winds and birds—all contribute to weed growth either directly or indirectly and thus add to the burden of control.

Rigid control of weeds is essential in obtaining maximum crop yields, but the control is costly. The employment of hand-operated mechanical devices to subdue weed growth is rapidly receding as an effective means of control. Labor is scarce and expensive. The hoe and soil scraper do discourage annual weed pests, but actually they transplant and spread many of the more hardy weed types.

[1] This is the first of a series of papers describing progress in chemical weed control research, beginning with 1944.

[2] In collaboration with F. C. Denison, Q. H. Yuen, R. C. Miller, and P. B. Kim.

Spraying liquid chemical herbicides upon heterogeneous weed growth, where the destructive action of the herbicide denudes vegetation above ground, upsets the ratio of annuals to perennials and in due course results in the expansion or spread of the hardier grasses at the expense of the more readily controlled broad-leaf annuals. In such cases the grasses recover; the annuals do not survive and hence, eventually, the grasses become predominant in the weed population (see Figs. 1 and 2).

Fig. 1. Previous weed control by hand hoeing. Note new growth of broad-leaf weeds.

The trend to favor grasses by our present system of chemical weed control has been made more pronounced in recent months where physiologically acting hormone spray solutions have been applied as a supplementary spray to cane foliage entwined or choked with honohono (*Commelina nudiflora*) or morning glory (*Ipomoea*). The hormone (2,4-dichlorophenoxyacetic acid), applied to foliage at 1,000 p.p.m., exerts no destructive action upon the cane or upon common field grasses in the area under treatment. Hence the major problem of weed control in Hawaiian cane lands has become one of controlling grass growth.

Many grasses, commonly found in cane lands, reach a height of from six to eight feet, if undisturbed. They produce a compact cover and root deeply in separately established mounds or clusters. When thoroughly sprayed by a contact herbicide, the function and vigor of such grasses are markedly affected, but the effect is only temporary. In a few weeks recovery sets in not only from the root systems, but from many apparently fatally injured terminal and lateral buds, particularly those protected by sheath-like coverings at growing points. At about three days after a thorough spraying has been applied, the grasses assume the appearance of complete destruction. They will be found shrunken,

brown and brittle. In spite of appearances, an undamaged strand of viable tissue may be found along the inner longitudinal channels of many of the stems.

Similarly, green tissue may later be observed at growing-point extremities but, as a rule, it is surrounded by several layers of tightly adhering brown and brittle fibrous material, the latter having been destroyed by the spraying. Obviously, then, a rapid-acting contact herbicide, even though entirely effective upon broad-leaf annuals and young grass seedlings, is definitely not permanently destructive upon mature perennial grasses predominant in Hawaiian cane lands.

It was found, however, that all tissue of mature grasses would be destroyed provided actual and intimate contact of herbicide and tissue was effected. It became essential, therefore, to employ a substance incorporated with the herbicide which might either tend to unfold concentric layered external integuments of the grasses or exert a penetrating influence through such external cellular tissue and thus carry the herbicide to the inner vital portions of the plant.

Fig 2. Previous weed control by chemical sprays. Note predominance of grasses in new growth.

The choice of a suitable herbicide is governed not only by initial cost of materials, but, equally as important, by its non-toxic effect upon the men preparing and applying it. It is also most essential to use a herbicide that will not injure the soil either by temporary superficial sterilization or by deposition of poisonous substances which eventually reach the soil solution and thus, through this avenue, the crop.

The staff of the Chemistry department of this Experiment Station has been committed to the development of a satisfactory contact herbicide. Research on this problem has been in progress for a number of years. The objectives of the research are few, but most emphatic. They are:

1. To produce an effective herbicide, non-poisonous to man, beast or soil.

2. To formulate a process of simplicity, employing chemical constituents readily obtained by specification on open markets and economically advantageous.

3. Development of a herbicide which has a high contact effect without leaving a residue to reach eventually the soil and induce sterilization, or spread to and damage the root systems of the principal crop.

4. Produce a so-called "concentrated" herbicide which may be diluted with water prior to application without employing expensive or cumbersome mechanical devices.

The purpose of this paper is to set forth the progress made to date (1947) in our efforts to meet the objectives of this undertaking.

Commercial Chemicals as Herbicides:

In a previous paper (1) a review was presented describing most of the chemical compounds which had been used throughout the world for weed control purposes. Either on the basis of prohibitive costs or general inefficiency, many of these chemicals were ruled out for intensive study in Hawaii. Since that time newer and more effective compounds have been placed on the market, but the disadvantages of high cost and unsatisfactory efficiency, particularly on hardy and vigorous grasses, have rendered all of those studied so far as not entirely acceptable. A notable exception, of course, is the recently developed, selective, synthetic hormone, 2,4-dichlorophenoxyacetic acid, and derivatives therefrom. A discussion will be presented later of the results realized in the now current research on this class of herbicides.

One outstanding fault of commercial chemicals, which have been found satisfactory when used to control weed growth on mainland cereal crops, is the selective nature of many of these compounds in relation to the tolerance of grasses to their herbicidal effect. At first thought it might be proposed that since these compounds do not affect grasses, and since sugar cane is essentially a grass, they should prove ideal for our purpose. It is true that grains, too, are grasses and since the major weed growth on mainland grain fields is composed of broad-leaf weeds these selective chemicals have been found quite efficient. Other factors favoring their use on mainland grain fields pertain to the short crop cycle of grains, the rapidity with which grains grow and ripen, the limited season of weed growth and propagation, and the destructive effect upon all weed development by frost and freezing temperatures in the long winter months' fallow of grain fields.

On the contrary, the major weed growths in Hawaii are hard grasses, and the development and propagation of all weeds are luxuriant and continuous. Even if one or more of the new herbicide chemicals were found satisfactory in Hawaiian sugar lands, the cost per unit volume of effective spray solution prepared from them (not including the hormones) would indeed render all of them inadequate as effective substitutes for much cheaper herbicides.

The one possible exception to the above statement is the combination of sodium chlorate and H.S.P.A. Activator* in a solution containing 20 pounds of sodium chlorate and 4 pounds of the H.S.P.A. Activator dissolved in 100 gal-

*U. S. Patent No. 2,370,349.

lons of water (2). This solution does not need any added wetting agent. It is non-poisonous, at least to a partial degree, and rather generally meets the requirements of the conventional "contact" herbicide. Its principal disadvantages are an acute fire hazard when in storage or after dilution and its drying out on sprayed vegetation. It also has a tendency to sterilize soil.

Petroleum as a Herbicide:

It has been known and recognized for a number of years that certain portions of distilled petroleum exert a marked and selective herbicide action on vegetation, particularly grass growth. Petroleum is definitely non-poisonous. When compared on a basis of cost per pound with manufactured chemicals, many petroleum products enjoy a decided advantage in this important respect. However, it is physically and chemically difficult, if not impossible, to concentrate petroleum. To employ these materials, without treatment or modification, as they emerge from the oil refinery is likewise uneconomical. The large volumes required and consequent handling costs involved, together with unit gallonage outlay, would completely and entirely eliminate this class of chemicals as satisfactory spraying herbicide materials.

On the other hand, since most petroleum products are non-poisonous and since most of them do exhibit effective herbicidal effects on grasses in their own right, it became a matter of looking into the possibilities of employing one or more of these substances as basic material in the development of a satisfactory cane-field herbicide.

To achieve this objective it was at once apparent that the research on the project must be directed to:

1. A fortification or other chemical treatment of the oil to stimulate the high concentration made possible when using certain water-soluble, inorganic salts for similar purposes. (This requirement is essential to meet the economies of field transportation, dilution with ditch water, and cost of herbicide.)
2. A modification or treatment of the oil to render it freely miscible with water in any proportion for dilution in the field and for adherence to or absorption into unwanted vegetation containing up to 85 per cent moisture.
3. The preparation of a type of herbicide not only effective on grasses, but upon all common weed growth.
4. The inclusion of amendments which, even upon normal dilution, would ensure destruction of ungerminated weed seeds with which it may be brought in contact.
5. The formulation of a process which would disperse the oil fraction of the herbicide so effectively that recoherence of the oil would not occur and thus impair the tilth of the soil upon which it must eventually fall.
6. The formulation of a compound of non-poisonous properties but, in addition, one which would rapidly become dissipated in the soil by the combined action of oxidation, reduction and bacterial effects.
7. The development of a process of manufacture which would be simple, inexpensive, and which would produce a preparation of lasting and durable properties.

In previously conducted research studies made for the purpose of determining the synergetic range of the H.S.P.A. Activator upon numerous substances lethal

to vegetation, it was ascertained that the activator was outstandingly effective in the increased efficiency it imparted to emulsions of petroleum oils. It then became a matter, in this research, to determine first which type of emulsion would best carry the oil and activator in permanent dispersion, what quantities should be used, and by what means should the emulsion be prepared.

The H-109 Formula:

Following preliminary laboratory study in Honolulu, the research was expanded to a larger scale at the Waipio Substation in cooperation with and under the auspices of F. C. Denison, in charge of that substation. Mr. Denison erected a vertical steel tank, having a capacity of 200 gallons, upon an elevated platform. The bottom of the tank was provided with a shutoff outlet so that the contents could be discharged to containers placed below it. A portable agitator consisting of a long shaft terminating in a motorboat-type propeller was lowered into the tank, the propeller being placed close to the bottom. The support for the agitator consisted of a clamping device attached to the upper and open rim of the tank. The tank was charged with a solution consisting of:

109 gallons of water
10 pounds H.S.P.A. Activator
1 gallon 2-7-R solution*.

The agitator was rotated by an electric motor and allowed to run continuously at a speed of 1,750 r.p.m. Ten gallons of Diesel oil were then introduced in a slow, steady stream and agitation was continued until a fairly stable emulsion was produced. When prepared in this manner, the oil entered the inner phase of the emulsion and the water occupied the outer phase.

Extensive field study and observations were made of this emulsion, without further dilution, for a period of several weeks. Mr. Denison found that without further dilution this preparation was more potent than was necessary to control the average weed growth to be found in the fields of his substation. It also developed that the oil in the emulsion attacked rubber hose and rubber gaskets in the regulation spraying equipment from which the emulsion had been applied to grass and weed growth. He found that the preparation was equally as effective on all common broad-leaf weeds as it was on hard grasses. This finding was important for it suggested that the selective action of Diesel oil upon grasses had been broadened by emulsification and activation to a more general-purpose herbicide. This accomplishment was one of the objectives of the research.

The deterioration of rubber by the action of Diesel oil was overcome by substituting any one of several grades of synthetic rubber manufactured expressly for the purpose.

In regard to the apparent excessive potency of the H-109 formula, a choice was at hand to either reduce oil and activator in the emulsion, or simply reduce the amount of water in the formula. This would be the first step in the sought for objective of producing a concentrated emulsion capable of dilution in the field prior to application of spray.

The second choice was adopted. The volume of water in the original formula was reduced to 49 gallons; the new formula became the H-49 Concentrate.

* Two pounds 2-7-R paste dissolved in sufficient water to make 1 gallon of solution.

Several weeks of study with the new formula convinced Mr. Denison that for average light weeding operations the H-49 Concentrate could be safely diluted with four times its volume of water. This finding was encouraging, but we were faced with the fact that the H-49 emulsion was actually a very poor emulsion and, unless it was diluted and applied immediately after being manufactured, a sharp separation of oil and aqueous portion of the emulsion would take place within a few hours after its preparation. A more effective plant-scale means of emulsification was clearly indicated. It was also believed that a formula could be developed which would be capable of still greater dilution. At the same time, it was realized that a two-package job was inevitable because of the salting out or breaking effect upon the emulsion of higher concentrations of the activator, which must be used in a more concentrated setup. The problem then became one of improving the emulsification process, increasing the Diesel oil to the maximum consistent with stability, devising a means of incorporating the activator upon dilution of the oil emulsion, and including sufficient suitable wetting agent in the process to facilitate thorough coverage of sprayed foliage during application. Since emulsification of oil and water in the laboratory to a fine degree of stability is not at all difficult, the entire problem was shifted to Honolulu for continued laboratory study.

Improving the Emulsification Process:

In considering the manner of oil emulsification, in view of the failure of mechanical stirring devices to perform adequately this operation on a large scale, it was decided to study the problem on a basis of spherical diameter of dispersed oil globules in the emulsion. The problem had resolved itself into the simple mechanical matter of breaking up individual oil particles to such an extreme degree that very large surface areas of the oil would be created in the process. This would facilitate the function of the emulsification agent to surround the minute oil globules with a more permanent and stable interphase of dispersing medium—water. It was our belief that this operation of breaking the oil—dispersion to a very small globule size—would also contribute to more effective absorption of the oil through the plant cuticle.

In discussing this problem with J. R. Lowrie, Superintendent of Pilot Plants at this Experiment Station, he suggested that the process of homogenization might solve the problem. It developed that the operation of homogenization took place out of contact with air. As a result, the disturbing matter of heavy foaming, as produced by open centrifugal agitation, could thus be eliminated. Mr. Lowrie offered his cooperation in developing a homogenizing process.

The problem was submitted to Dr. Harold L. Lyon, Director of this Experiment Station. Dr. Lyon immediately approved the plan and authorized the purchase of suitable used apparatus and the participation of Mr. Lowrie in the study.

An old, abandoned homogenizer, having a capacity of approximately 125 gallons per hour of output, was located and purchased. Mr. Lowrie took down the machine, rebuilt it, and replaced worn parts, devised and constructed accessory equipment, and set up the whole assembly in his laboratory as a continuously operating unit. In the meantime, a process of emulsification was developed in the chemistry laboratories for experimental trials in the homogenizing unit.

In a number of emulsification researches reported in the literature, findings were described which indicated that an oil-in-water emulsion would not remain stable if the oil in the mixture was present in an amount greater than about 72 per cent. These findings were verified in our laboratory, using the materials which made up the H-109 and H-49 formulas (previously described). By further experiment, it was also determined that the presence of about three-fourths of one per cent of H.S.P.A. Activator would materially stabilize a 70 per cent oil emulsion. When the concentration of H.S.P.A. Activator reached about four per cent or more in the finished emulsion, a sharp break out of oil occurred and the emulsion was destroyed. This occurrence, of course, was due to the salting out effect of the ionic fraction of the activator. It had been anticipated. It was deemed worthwhile, in this connection, to experiment further in seeking to by-pass this phenomenon by substituting the oil-soluble parent pentachlorophenol (Oil-Soluble H.S.P.A. Activator) for its water-soluble sodium salt, then currently used. The purpose of its use would be to produce, if possible, a single, highly-concentrated stock emulsion containing all the materials necessary to produce an effective herbicide upon dilution to many times its original volume, simply by adding ordinary tap or ditch water.

This study was postponed, however, because of the urgency to devise a satisfactory homogenizing or large-scale emulsion formula on the basis of the development as it had progressed to this point. The necessity for using a secondary concentrated water solution of H.S.P.A. Activator in the field diluting program was recognized as essential in the setup as it existed. This requirement had likewise been anticipated.

In the development of the large-scale emulsion formula, it was decided to reduce the Diesel oil percentage in the emulsion from the theoretical safety ratio of 72 per cent oil to 28 per cent water to the values of 67 per cent oil to 33 per cent water for the following reasons:

1. To allow a five per cent margin of safety for machine operation.

2. To impart a certain flexibility to the product itself in maintaining its stability. By formulating the product on the 67-to-33 ratio, the emulsion could, by exposure to evaporation or by careless handling, part with about five per cent of its water and still remain perfectly dispersed and thus retain its original stability.

The CADE Formula (CADE Indicating Concentrated Activated Diesel Emulsion):

The laboratory study for the experimental machine homogenization of the emulsion was finally developed as follows:

1. The aqueous portion of the emulsion consisted of 14 pounds of Wetting Agent 2-7-R (a water-soluble sulphonated aromatic paste), seven pounds of H.S.P.A. Activator (used in this case as a stabilizing agent), and sufficient water to produce a solution having a volume of exactly 33 gallons.

2. The oil portion of the emulsion consisted of exactly 67 gallons of Diesel oil meeting Pacific Specification 200 (P.S. 200). These two liquids were to be delivered by gravity to a pre-mixing container at a constant ratio of two volumes of oil to one volume of water. Provision was made for mild agitation of the pre-mix as it would be drawn from the pre-mixer by suction into the homogenizing chamber of the apparatus. Mr. Lowrie calibrated his equip-

ment according to this predetermined scheme. The emulsification of the two liquids would produce 100 gallons of product.

The first trial of Mr. Lowrie's apparatus proved entirely successful. During this initial run he determined that a pressure of 2,500 pounds upon the homogenizing valves resulted in the formation of a smooth, creamy emulsion of ample fluidity and, as it later developed, of perfect stability. A laboratory study of this emulsion indicated that the globule diameter of the dispersed Diesel oil had been reduced to a quite uniform and average diameter of one micron (0.000039 inch). This enterprise on Mr. Lowrie's part appeared to dispose of the problem of manufacturing a practically perfect CADE formula by machine emulsification. His final product was free from entrapped air and was delivered by his apparatus at the rate of about 125 gallons per hour.

This experimental study also contributed to the solution of the problem which required the maximum possible volume of dispersed Diesel oil in the CADE emulsion so that the matter of concentrating the product to the utmost could be accomplished. This requirement was intended to concentrate the CADE so that a much greater dilution of it could be made in the field and, hence, add economy to its utilization.

The next phase in the study included means of providing a simple and economical method of introducing the synergetic agent (H.S.P.A. Activator) and the wetting agent to the diluted CADE, just prior to its application in the field.

In agreement with theory, it was found that the emulsion would be broken at once if a concentrated solution of the H.S.P.A. Activator were added to CADE, and the preparation would be ruined for purposes of weed control. On the other hand, it was determined that the CADE could be incorporated with complete safety if the concentrated activator solution was first added to the diluting water normally used in the field. The net result would simply ensure a dilute emulsion entirely stable and homogeneous, and in prime condition for application to weeds and grasses. The optimum amount of wetting agent to use in the process was determined by experiment in the field. An amount was decided upon slightly in excess of that required to thoroughly wet the most resistant foliage and hairy grass stems to be encountered.

The Stock Solution of H.S.P.A. Activator (SSA):

A concentrated Stock Solution of H.S.P.A. Activator and wetting agent was formulated. It proved quite feasible and economical in field practice, in spite of the fact that it was necessary to resort to the two-package scheme of concentrate for field usage at this stage of the development. The SSA was prepared as follows: 120 pounds of H.S.P.A. Activator and 20 pounds of Wetting Agent 2-7-R were dissolved in sufficient water to make a final volume of exactly 100 gallons. After several months of field study, where running ditch water available at convenient points on all irrigated plantations was used, if possible, a dilution factor of 1-in-16 was found adequate for average heavy weed and grass growth in the drier districts of the Territory.

The herbicide so prepared operates lethally upon vegetation by contact, and not physiologically. Therefore, it affects only the above-ground portions of sprayed plants. It destroys annuals outright, but functions on grasses similarly to other inorganic contact weed killers. Young seedling grasses are destroyed by

the application. However, established heavy growth of hard or perennial grasses suffers only a severe setback, unless a much heavier application of a more concentrated formula is made. As a rule, mixing operations are set up on the ditch bank, where knapsack spraying is to be used. It has been established that 100 gallons of CADE and 50 gallons of SSA will provide a full day's work for a crew of 12 knapsack spray men.

The Mixing Procedure in the Field:

Exactly 145 gallons of water are placed into a container having a capacity of about 200 gallons. The gang luna then adds five gallons of SSA, stirs it a moment and then adds 10 gallons of CADE. He stirs it again a few moments and then transfers the diluted herbicide to the individual knapsacks. This operation prepares 160 gallons of an effective herbicide from 10 gallons of the concentrated CADE and five gallons of the prepared Stock Solution of H.S.P.A. Activator, the dilution factor in this case being 1-in-16 (one gallon of CADE in 16 gallons of diluted emulsion). The water is supplied from the irrigation ditches or it may be piped or hauled to strategically located, semi-permanent mixing stations.

The above illustration applies, in a general way, to knapsack spraying of weeds and grasses within the cane field proper, and along and between the cane lines before the cane closes in.

The first application in a field is usually made within a week or ten days after the cane seed has been planted, or after the previous crop has been harvested and the field has been prepared for a succeeding ratoon crop cycle. The weed and grass growth, in either case, will be young and tender when the first spraying is made and will not require as potent an application of herbicide. For applications of this type, the spray solution may be pumped directly or broadcast from tanks under pressure, mounted on a trailer or tractor and serviced by air compressors similarly mounted. Various types of nozzles are used at fixed positions on the spraying manifold. The delivery of spray is regulated to cover the entire ground surface of from 6 to 10 feet in width as the power-driven equipment moves back and forth across the field. A dilution ratio of 1-in-20 or 1-in-24 may suffice for this operation. A thorough application will destroy all succulent weed growth, both grass seedlings and tender annuals. At the same time, many of the exposed weed seeds on the surface of the ground will be destroyed or germination will be inhibited.

Later, when the cane has reached a height of from three to five feet, a knapsack spraying may be applied or a high-clearance tractor may be operated so as to discharge a diluted spray emulsion between the cane lines. In any of these applications the damage to the cane is usually insignificant.

In dry country, on irrigated plantations, 100 gallons or less of spray emulsion per acre may be sufficient. In wet districts of high rainfall, as much as 500 gallons may be required per application, depending upon the vigor and height of weeds and grasses—chiefly grasses. From two to five rounds of spraying may be necessary to maintain weed control until the cane has closed in.

The Limitations of CADE Efficiency:

The CADE formula and processes of dilution, activation and application have proved generally satisfactory on irrigated plantations. At his plant at

Waipio, Mr. Denison is manufacturing from 12,000 to 15,000 gallons of CADE per day, using two homogenizer units as designed, set up and calibrated by Mr. Lowrie and himself. The output of this plant is used as regular practice at the Waipio Substation (119 acres) and by plantations on the Island of Oahu.

Shipments of 100 drums or more of CADE are forwarded by steamer for experimental study on the Island of Hawaii. Local manufacturing plants are operating similarly on several plantations situated on the Islands of Maui and Kauai.

The adoption of CADE in preference to other chemical herbicides is gaining rapidly throughout the Territory. The fact remains, however, that the CADE formulation is not sufficiently potent to compete economically with harsh inorganic and highly poisonous spray solutions, when comparison is made on the basis of immediate results as obtained in wet districts upon rampant grasses in an environment of moisture conditions which approximate saturation.

Therefore, the CADE program of weed control has not enjoyed universal acceptance by plantation managements on the Island of Hawaii. In fairness to the CADE program, however, it should be added that when applied in ample amounts and at higher concentrations, when rain is not falling, CADE has been proved superior to existing contact herbicides, but the cost of materials used has been somewhat higher. It became necessary, therefore, to embark upon an intensive study to determine the inherent weaknesses of CADE as presently prepared and to devise ways and means of increasing its potency without materially adding to its cost of production.

The Activation Principle:

It had previously been established that, given any suitable lethal herbicide constituent sensitive to our system of activation, the potential of increased potency of killing effect was essentially a function or a factor of the natural destructive effect of the parent herbicide itself.

For example, in the case of sodium chlorate, three pounds of H.S.P.A. Activator and 20 pounds of sodium chlorate in 100 gallons is actually a superior herbicide to 40 pounds of the chlorate in the same volume of spraying solution.

The comparison is more striking in the case of the Diesel oil emulsion. It has been found that an emulsion containing as much as 10 per cent by volume of Diesel oil is indeed a most feeble herbicide without imposing upon it the synergetic effect of about one-half of one per cent of the H.S.P.A. Activator.

It appears most likely, therefore, that the weakness exhibited by CADE must be sought in the oil portion of the preparation and not in the system of activation which was being impressed upon it. This theory was subjected to a somewhat elaborate laboratory study in cooperation with Mr. Denison, the latter carrying out a large number of small-plot field studies using a long series of special CADE formulations.

Small lots of new CADE formulae were prepared in the laboratory at Honolulu in which:

1. New emulsifying agents were used.
2. The Oil-Soluble H.S.P.A. Activator was partially or entirely substituted for the water-soluble form.
3. Other available petroleum oils were substituted for Diesel oil.

4. Oil-soluble chemicals of various types and in graded concentrations were added to the Diesel oil prior to its emulsification, with and without the impressing of activation on the product.
5. Sharply separated individual distilled fractions of Diesel oil, from the lowest to the highest boiling points, were formulated into special CADEs, using the regulation CADE process.

An additional purpose of this study was to test the efficiency of the emulsification agent then in use and to determine its ability in establishing an interfacial barrier in the emulsion which would not give way to the breaking action of added ionic constituents. The 2-7-R emulsification agent failed to resist ionic additions. Experimental batches of CADEs in this part of the study never reached the testing plots at Waipio. The heavy gelatinous dispersing agents were more successful in this respect, but even so the emulsion stability so obtained was achieved only be increasing the viscosity of the product to a point where cost factors and ease of handling defeated the effort.

The oil-soluble activator gave encouraging results when it was dissolved in the oil prior to emulsification. The comparatively low solubility of the oil-soluble activator in Diesel oil limited the scope of experimental study in this portion of the research. It was found necessary to use the water-soluble activator to impress the full activation effect. Under no circumstances was it found possible to combine the individual or the two forms of the activator in an all-purpose, one-package job capable of simple dilution with water for application in the field. The effort was not abandoned entirely, however, for it was believed that more modern and more efficient emulsifying agents might contribute to a solution of the problem. An investigation along this line is now in progress.

The substitution of mainland-prepared petroleum oils, other than Diesel oil, gave very promising leads, especially those oils which carried 50 per cent or more of aromatic or naphthenic constituents. As a matter of fact, the pronounced improvement of potency in some of these oils and their added potential of efficiency by activation gave the first impetus to the organization of the mainland survey of the herbicidal properties of petroleum refinery and cracking plant residues which is now under way. In this preliminary study, the excessively high cost of mainland-manufactured or compounded special petroleum oils rendered their use on a large scale in Hawaii as definitely out of the question. Nevertheless, the findings in this study were considered invaluable as leads for more intensive survey and research.

The addition by solution of a large variety of chemicals as fortifying agents to Diesel oil before emulsification gave considerable promise of ultimate value in new developments. But, as a rule, greater efficiency of herbicidal effect, when carried to the point of outstanding improvement, carried with it a factor of increased cost of production, which was simply extravagant and impracticable in most cases.

An effort was made in this study to impart greater penetrating properties to the diluted herbicide emulsion by the addition of synthetic substituted aromatic ethers, but again the high costs involved to influence appreciably the concentrated emulsion that this added property would prevail upon normal dilution were entirely out of line. The diluting action of the penetrant upon the potency of the compound, when present in an efficient functioning concentration, brought

into consideration the matter of diminishing overall accomplishment of purpose. This effort was not a success.

The preliminary study of herbicide effect of the sharply separated individual distilled fractions of Diesel oil, under activation, yielded the most encouraging findings of the entire research program. It was determined in the early part of the study that the lighter boiling fractions of Diesel oil were inferior to the higher boiling fractions. When defined somewhat more specifically, it developed that the first 50 per cent fraction distilled from Diesel oil could be classed only as a rather indifferent herbicide. The remaining residue (the second 50 per cent) was outstanding in its weed-and-grass-killing properties and superior by far to any other development of like simplicity which had previously been produced. This finding included the regulation CADE formula in the comparison and in all cases was based on the standard activation treatment of test product, using one-half of one per cent of H.S.P.A. Activator.

Mr. Denison originally established this finding and subsequently re-proved it in a large number of field tests carefully conducted in using ample replicated control plots. The problem then became one of sharpening the separation of Diesel fractions to determine quantitatively the herbicide value of each sharp fraction, its physical properties and its chemical composition, both empirically and by organic groupings. We were aided at this point in the study by the return to duty at the Experiment Station of our former collaborator, Q. H. Yuen, who had served with distinction with the U. S. Army in World War II.

The expansion of the research program, which had now become more clearly defined, required the services of additional research personnel. Peter B. Kim was transferred from other duties in the department to engage in weed control research activities and a new member, R. C. Miller, joined the chemistry staff for other research assignments in the weed control program. A field assistant was engaged for Mr. Yuen to take over routine glass-house and field-plot duties in the quantitative herbicide evaluation studies which Mr. Yuen had gotten under preliminary development.

Mr. Denison prepared an enlargement of the field-testing program at Waipio and began the training of assistants in order to take over a larger volume of field-study plots and at the same time keep his enlarged CADE plant in continuous operation in order to meet the steadily increasing demand for this product. Mr. Lowrie stood by, prepared to volunteer his engineering skill as occasion might require.

A new and modern laboratory homogenizer was purchased for more closely linking small-scale laboratory developments with plant homogenization. By this means any successful laboratory formulation under controlled conditions could be reasonably certain of exact duplication under like conditions in the large plant equipment. Mr. Lowrie superintended the erection and calibration of the new laboratory homogenizer.

The Breakdown of Diesel Oil into Fractional Components:

Mr. Miller began research on this topic after having reviewed the subject in the literature. His purpose was to repeat our earlier experimental study. He also planned to devise a rectifying and fractionation unit having a capacity greater than the ordinary laboratory assembly of apparatus which is commonly

used in such work. He designed and constructed an excellent and modern laboratory unit. He made provision in his condensing system to operate the rectifier either at atmospheric pressure or at an approximate vacuum. In the output of the condenser, a system of by-pass calibrated collection chambers of Pyrex glass, delivery to which was controlled by built-in glass stopcocks, was fabricated and installed for Mr. Miller by P. L. Gow, Associate Chemist. Safety traps surrounded by low-temperature cooling baths were installed in the condensing system. Thermal insulation of the distilling or rectifying chamber consisted of closely-wound asbestos rope. A large container of dry sand was placed below the high-temperature portion of the apparatus and a fire extinguisher of liquid carbon dioxide was installed within easy reach.

In the fractionation of Diesel oil by controlled distillation, Mr. Miller established a pattern of procedure which resulted in the breakdown of original specimens into ten components of equal volume. The first nine components were collected progressively in the ascending order of their boiling points, the tenth portion consisting of the undistilled residue in the distilling chamber. The initial and final boiling points of each distilled fraction were noted as well as the initial boiling temperature of the residue. The bromine number, aniline point, per cent aromatics and per cent unsulfonated residues were determined on each of the ten components.

The per cent olefines, in each case, are calculated from the data and the amount of paraffins and olefines present are also estimated by similar means. These data are very significant as criteria of physical and chemical properties of an oil, or a distilled fraction of an oil, in evaluating it in terms of its herbicidal performance. These data also are invaluable in characterizing an oil, or fraction thereof, in terms of its "potential of activation". The term "potential of activation" is employed to designate the gain in weed-killing ability which takes place as a result of combining with any emulsified oil the standard one-half of one per cent of H.S.P.A. Activator in the final diluted product which is ready for application in the field. Thus, an activation potential of 300 would indicate that the weed-destructive properties of an oil had been enhanced three-fold, or 300 per cent, by the synergetic effect of the H.S.P.A. Activator on that oil.

A typical example of one of Mr. Miller's fractionating studies is included below:

"The following is a brief summary of work completed by the writer on Diesel oil.

DIESEL OIL (P. S. 200)

Fraction No.	Initial B.P. °C.	Initial B.P. °F. (approx.)	Bromine No.	Aniline Point (°C.)	Aromatics % (approx.)	Approximate % Unsulfonated Residue
1	183	361	3.0	55	25−	79
2	240	464	2.6	58	25−	79.5
3	255	491	2.6	60	25	77
4	267	513	2.6	62	25+	77.5
5	278	532	2.6	64	30−	78.5
6	290	554	2.6	66	30−	74.5
7	302	576	3.0	68	30	74
8	315	599	3.4	70	30	72
9	330	626	3.9	72	30+	73
10	349	660	9.4	—	35+	68.5

"Unsaturation indicated by bromine number may be due to double bonds in side chains of aromatics and naphthenes (as suggested in Standard Oil Co. data), or may be due to olefines present. Estimates based on the deduced formula:

$$\% \text{ Olefines} = \frac{\text{Bromine No. x mol. wt.}}{160}$$ amount to less than five per cent

for the first nine fractions. The much higher number for Fraction 10 is believed to have been caused by cracking during fractionation. In either case, unsaturation is low.

"Paraffins and naphthenes were estimated by determining the aniline point of the unsulfonated residue for each fraction of oil and interpolating with available data for paraffins and naphthenes of that boiling range. Paraffins average 10 per cent—; naphthenes 60 per cent+.

"Some work was done on the extraction of the aromatic portion of No. 8 combined with No. 9, with aniline and selective solvent. Results indicate that the mixture of hydrocarbons most easily extracted (therefore having lowest aniline point) are the lethal hydrocarbons, and have the highest index of refraction.

"Experiments with Fraction No. 10 indicate that it is an oil which is slightly heavier than No. 9, with asphaltic and tarry compounds held in solution. As yet, only small quantities of the clear portion of No. 10 have been extracted; its lethal powers are not fully known, but it is suspected that the No. 10 fraction is as lethal as No. 8 or No. 9, except that the physical properties of the tarry and asphaltic substances cause a poor wetting effect upon application.

"A search of 'The Physical Constants of the Principal Hydrocarbons', (1943, M. P. Doss of the Texas Co., author) indicates that the hydrocarbons with the highest index of refraction are those with the highest percentage of carbon. A number of aromatics *with unsaturated side chains* are listed, but their boiling points are too low for the Diesel oil fractions in question. Also, the bromine number for Diesel oil indicates unsaturation is low. The lethal hydrocarbons are believed to be di⁻, tri⁻, or tetracyclic hydrocarbons, but most may be dicyclic. Studies of the lethal oils 38-R and 39-R help bear this out.

"The new Diesel oil has not been investigated as fully as P.S. 200, but the following data are submitted.

NEW DIESEL OIL

Fraction No.	Initial B.P. °C	Initial B.P. °F. (approx.)	Aniline Point (°C.)	% Aromatics (approximate)	Approximate % Unsulfonated Residue
1	185	365	52	25—	78
2	235	455	55	25+	78
3	248	478	57	25+	78
4	258	496	58.5	30—	74
5	266	511	60.5	30+	74
6	274	525	62	30+	74
7	283	541	64	35—	72
8	291	556	65.5	35—	74
9	302	576	67	35—	72
10	321	610	68.5 (indirectly)	35	66

"The result of one bromine number determination was 0.8. Estimates from aniline points place the paraffins at 20 per cent—; the naphthenes at 50 per cent for the whole oil. A high percentage of aromatics throughout is believed to be the cause of results comparable to those given by Diesel oil (P.S. 200)."

After having separated an oil into ten component parts, as illustrated above, and having determined or calculated significant chemical and physical properties of each fraction, Mr. Miller may test certain fractions in glass-house studies or in individual small pot cultures of hard grasses. In all cases, however, he prepares a sufficient volume of each fraction to permit the completion of an organized quantitative glass-house and pot study of each fraction and of the parent oil itself. The latter acts as a control for purposes of comparison along with a second control consisting of standard CADE practice.

This system of herbicidal evaluation of an oil and its component parts has been developed by Mr. Yuen and has become standard practice in our investigational studies. The parent oil and its components are separately subjected to rigid tests in which:

1. The performance of the undiluted or untreated oil itself is determined.
2. The behavior of the specimen upon emulsification and dilution is ascertained.
3. The gain, loss or failure to respond to H.S.P.A. activation is measured upon specimens which have been homogenized, diluted and activated by regulation CADE procedure.

Mr. Yuen employs the laboratory homogenizer in the preparation of specimens and determines certain other physical characteristics of each oil fraction as a part of the herbicide evaluation study. He describes below the full technique of the evaluation:

"To determine the comparative effectiveness of an oil or a cut of the oil against Diesel oil, the sample is subjected to three spray tests. They are straight oil, emulsion, and activated emulsion. The emulsions, with and without activation, are prepared in appropriate dilutions. The indicator crop is California grass or Panicum grass (*Panicum barbinode* Trin.), growing in Mitscherlich pots.

"The Mitscherlich pots are approximately seven and three-fourth inches in diameter and about seven inches high. About four kilograms of air-dry Manoa soil are put in each pot. The planting consists of fourteen cuttings of the California grass. When the cuttings have germinated and the growth is about six to eight inches high, the pots are fertilized with Ammo-phos and potash sulfate so that each pot will contain about two grams of nitrogen, nine grams of P_2O_5 and two grams of K_2O. Water is applied daily or as needed to exclude moisture becoming the limiting factor. When the plants are about 30 inches high, they are ready to be used for the spray tests.

"The comparative indices determined for a petroleum herbicide are: SOI—Straight Oil Index, EI—Emulsion Index, and AP—Activation Potential.

"*SOI—Straight Oil Index:*

"The effectiveness of an oil sprayed straight, without emulsification or activation, is compared with the effectiveness of Diesel oil similarly sprayed. The amount of oil per spraying is that which will thoroughly wet the foliage, without restriction as to milliliters per pot or gallons per acre. The effect produced by

the straight Diesel oil is considered as an index of 100. The index for the test oil is determined by inspection of the results produced and an estimation of the appearance and rapidity of kill and recovery. The Diesel oil spraying usually will produce a withered and dried, brownish appearance, with wilted growing points. The wilted growing points of the Diesel-sprayed California grass are usually erect. Recovery of the Diesel spray pot will be exhibited in the growing points and tillering at the base of the plants near the soil.

"*EI—Emulsion Index:*

"An emulsion of Diesel oil and the test oil is prepared by homogenizing 200 ml. oil and 100 ml. aqueous emulsifying liquid. This aqueous emulsifying liquid is prepared by diluting 200 ml. of 2-7-R solution (two pounds 2-7-R Wetting agent per gallon) to 1,000 ml. total volume with water. The Diesel oil emulsion is diluted 1-in-2, 1-in-4, 1-in-6, and 1-in-8. The results produced by the Diesel emulsion at these dilutions are the bases of comparison of the test emulsion diluted at 1-in-6. The emulsion index is the measure of effectiveness of an emulsion of an oil or cut of an oil sprayed and compared with an emulsion of Diesel oil. Diesel oil effectiveness equals 100.

"For example: If the 1-in-6 dilution of the test oil should show results equal to 1-in-2 of the Diesel emulsion, then the EI of the unknown is equal to 300.

"*AP-Activation Potential:*

"The activation potential is a measure of the effectiveness of an activated emulsion of an oil or cut of an oil sprayed and compared with an activated emulsion of Diesel oil. Diesel oil effectiveness (activated) equals 100. Activation is produced with H.S.P.A. Activator (sodium pentachlorophenate). The amount used is such that the concentration of activator alone will not function to the extent of a straight herbicide. Our experiences have shown that seven and one-half pounds of H.S.P.A. Activator per 100 gallons of final spray is the maximum concentration to be used for this work.

"The emulsion used is the same as used in the emulsion index determination. Using seven and one-half pounds of H.S.P.A. Activator per 100 gallons of spray solution, the emulsion is diluted 1-in-4, 1-in-8, 1-in-12, and 1-in-16, in combination with the activator solutions. If the unknown activated emulsion, at 1-in-8 dilution, is equal to 1-in-8 activated Diesel emulsion, the AP is 100. If the activated unknown at 1-in-16 is equal to the activated Diesel at 1-in-8, the AP is 200."

Having previously found that the lighter boiling fractions of Diesel oil were inferior in weed-killing power to the higher boiling fractions, Messrs. Yuen and Miller took up the preliminary study where it had been terminated and repeated it on a more comprehensive scale in considerably greater detail, both analytically and by replicated quantitative glass-house and pot study.

As a result of this cooperative research it was determined that:

1. Diesel oil varies in chemical and physical properties and in weed-killing ability from time to time and occasionally from tanker to tanker as it is delivered in Hawaii from the West Coast.
2. Fractions 1 and 2 on a ten-fraction cut on Diesel oil have practically no value whatever as herbicides, either as is, or as emulsified and diluted 1-in-6, or as emulsified, activated and diluted 1-in-6, 1-in-8, or 1-in-10.

3. Fractions 3 through 7 may exhibit only slightly better weed-killing effects than the first two fractions, when similarly tested. As a rule, however, Fractions 3 through 7 are but mediocre as is and when emulsified without activation. When these fractions, singly or combined, are emulsified, activated, and diluted 1-in-16, they frequently accomplish a gain in killing effect at an activation potential of approximately 300.
4. A sharp change or break in inherent weed-destructive properties of the undiluted or untreated oil occurs in Fraction 8 and persists through 9, as well as the residue, Fraction 10. These oil fractions exert excellent herbicide effects when applied to weed growth directly. When emulsified, activated, and diluted 1-in-16, their killing effect is still further intensified. It is significant to note, however, that the activation potential rarely exceeds a value of 100.

Thus, somewhat in an empirical manner but with reasonable justification, we believe that the fractions of Diesel oil (P.S. 200) without treatment, additions, emulsification, or dilution may be classified:

1 and 2 as inert to vegetation
3 through 7 as indolent to vegetation
8 through 10 as toxic to vegetation.

Under emulsification, activation, and dilution at a ratio of one of special CADE, one-half SSA, in 16 of dilution with water, the so-treated fractions may be classified:

1 and 2 as inert to vegetation
3 through 7 (as a rule) as markedly toxic to vegetation
8 through 10 (invariably) as toxic to vegetation.

Hence, we find a differentiation on the herbicide properties of Diesel oil (P.S. 200) which is illuminating. It is most valuable in bringing to light data and natural characteristics of the oil which should serve as a reliable basis in the selection of a more potent and more effective petroleum product which may be substituted for a portion of it or preferably replacing it entirely.

The importance of pursuing further research was indicated by virtue of the fact that Diesel oil was subject to such marked variation in composition as normally compounded on the mainland for shipment to Honolulu. The outright necessity to carry on this study immediately and vigorously was decided upon in February 1947, when we were officially advised that P.S. 200 Diesel oil would be discontinued entirely and that other compounded oils of as yet undetermined herbicidal properties would shortly replace it in future shipments to Hawaii.

On the basis of (a) our background and understanding of promising materials to seek in petroleum for additional experimental study in an effort to utilize them with greater effectiveness and efficiency than was realized with Diesel oil, (b) the threatened withdrawal of Diesel oil from the Hawaiian market, and (c) the fact that Diesel oil itself, even at its best, was not entirely suitable, it was proposed to present the problem to all the major oil companies on mainland U.S.A. and request their cooperation in locating and identifying one or more outstanding suitable replacement oils. We had reason to believe that the most

effective herbicidal components of petroleum would be found among that larger group of natural constituents but present in low concentration in crude oil. Modern practices of refining of the oil yield objectionable, corrosive and otherwise toxic residues which must be removed from refinery output before marketing. In the aggregate, such undesirable residues amount to millions of gallons of fluid material. Compounds of this nature are generally harmful to machinery and working parts of industrial equipment. Also, as a rule, they are not harmful to men, animals or soil, when properly processed. It appeared certain that many of those products could be processed economically into strikingly efficient herbicides, especially by controlled activation.

The proposal for making an all-embracing survey and chemical research study among mainland refiners of the seven principal types of naturally-occurring crudes was submitted to Dr. Lyon. Dr. Lyon emphatically approved of the proposed mainland mission and authorized the immediate organization of the project. The matter was submitted to all the major oil companies operating throughout continental U.S.A. With very few exceptions, their full cooperation was tendered.

Executive and refinery officials of all the larger mainland oil companies were visited, beginning at San Francisco on May 26, 1947. A schedule of calls was arranged which allowed up to five consecutive days with each oil company staff. Actual refinery operations were observed and discussed. Provisions were made by most oil companies to include the inspection of glass-house and larger field-plot weed control experiments at nearby government or privately owned experiment stations. All companies contacted arranged round-table discussions with their scientific and executive staffs where our requirements were considered. Candid opinions were volunteered by all participants without reserve or restraint. Recommendations were submitted for our consideration. Generous drum-size samples of a large number of refinery products were reserved in most cases on the basis of developments accruing from these conferences. The companies thereafter shipped the selected oil specimens to our laboratory in Honolulu for further study.

Summarizing the discussions with oil company officials, we learned:

1. That Diesel oil is in heavy demand by railroads, trucking companies, and operators of power plants. The demand exceeds the normal supply and as a consequence this oil is being manufactured by new methods and processes. Its physical specifications will not be altered to any appreciable degree from the original P.S. 200, but its chemical composition will undergo marked modification.
2. That our earlier assumptions were in order regarding an available source of potentially promising residues in petroleum to be found as by-products, extracts, bottoms, etc. from outputs of modern thermal and catalytic petroleum cracking plants.
3. That these secondary residues carry chemical constituents which should prove more effective in weed-and-grass-destroying properties than any refined petroleum product of commerce.
4. That the chemical composition of most of these secondary residues embraced variable groupings of olefines, with and without branch chain structure, naphthenes, aromatics, and sulfur compounds.

5. That the source and type of crude oil, its degree and type of fractionation, characteristics of distilled gas oil fractionated, and method of its cracking all contributes to the chemical variability of the secondary residues.

The succeeding phase of this research will be devoted to the study of the oil specimens generously contributed by the major U.S. oil companies as a part of their cooperation in the survey on this topic.

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Weed Control Experiments And Practices In Sugar-Cane Production

A REPORT TO THE DIRECTOR, EXPERIMENT STATION, H.S.P.A.

By NOEL S. HANSON*

Following personal observations of outstanding successes in chemical weed control on the U. S. mainland, and conferences with recognized leaders in chemical weed control practices in 1947, an invitation was extended to Noel S. Hanson, Assistant Agronomist and weed specialist at the University of Nebraska, who was also president of the North Central States Weed Control Conference, to come to Hawaii for consultation, study, and work with our fieldmen who could benefit from his background of experience.

Mr. Hanson's three months in Hawaii enabled him to get a good grasp of local conditions and problems, and his visits to plantations were of definite interest and value. His complete report, which follows will be read with great interest.

(*R. J. B.*)

TABLE OF CONTENTS

INTRODUCTION

The selective destruction of undesirable plants in growing crops by chemical sprays, and also by soil treatments previous to germination or emergence of those undesirable plants, known as weeds, is a new agricultural science. At present it is gaining much emphasis and should logically continue to receive much attention in years to come.

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It was pointed out in the Report of the Agricultural Committee of the United States Chamber of Commerce in 1930 that the loss from weeds on farms in the continental United States was approximately three billions of dollars per year. This staggering loss was second only to the destructive forces of soil erosion in reducing income from crops, reducing land values, and impairing the health of both humans and livestock. The 1930 figure based on prices of that time would undoubtedly be half again as great at the present time. R. J. Borden states in *The Hawaiian Planters' Record* for 1944 (page 4) that from skirmish tests conducted by this Station, it has been found that weeds uncontrolled will reduce the yield of sugar cane by 70 per cent or more. When weed control was neglected for the first six weeks, there was a 45 per cent yield reduction even though full control was maintained thereafter.

Many of the good agriculturists, including farmers, ranchers, plantation, and technical personnel alike, have not been unaware of the seriousness of weeds and several states have passed legislation to bring the most obnoxious weeds under control. In the past the methods of control have been cumbersome and costly. Consequently, the great public willingness to act against these insidious enemies has been dependent on low-cost, effective methods of control. In Hawaii there apparently has been keen consciousness of the need for weed control. Chemical weeding by contact sprays has been practiced for many years; but improvement of the chemicals has been and is still desirable for more effective, lower-cost weeding.

With recently developed organic chemicals, many developed during the last war, the goal of low-cost, effective weed control is now closer at hand than has ever been true before. Along with the development of new chemicals have come improved methods of application. Consequently, there is at present an overwhelming desire among farmers, ranchers, and plantation personnel to rid their land of weeds. This is indeed encouraging to the exponents of good agriculture. This stimulated trend toward the use of the newer chemicals, such as 2,4-D, the dinitro compounds, the chlorinated phenols, and more recently the carbamates and salts of trichloroacetic acid, has developed within the period of the last three years. In this short period it has been utterly impossible, however, for research workers to establish the answers to the many questions that arise regarding rates of application, methods of application, relative effect on the weeds both by species and *en masse*, and the effect, whether desirable or undesirable, on the crop in which the weeds were treated. This is particularly true of soil treatments to prevent germination or emergence of weeds, a method which first gained emphasis in 1947. There is much speculation and very little conclusive information available about this method. Many fundamental studies must be conducted before these questions can be accurately answered.

From experiments conducted in the North Central States and Central Canada in 1947, the following statements summarize the main points that were learned about soil or pre-emergence treatments of 2,4-D under conditions that prevailed this one year: (From the Research Committee Report of the North Central Weed Control Conference but not in direct quotation.)

1. *Cereals:*

Experiments with 2,4-D pre-emergence on corn proved conflicting. Some evidence of injury to corn was reported from 2,4-D at some stations. Others

reported no injury even when planting immediately before or after treatment. There were scattered reports of stimulation of rooting of corn due to 2,4-D. These differences may have been due to soil and weather conditions or differences in hybrids.

Spring wheat and oats were, in general, less tolerant than corn. Fall injury to winter wheat, barley, and rye was not reflected in the yields. There was some indication of differential response to the various 2,4-D formulations.

2. *Legumes:*

   Alfalfa, sweet clover, and white clover proved susceptible to injury when sown within a month or six weeks after treatment.

3. *Forage Grasses:*

   The trials were very limited. Indications were that buffalo grass and intermediate wheat grass are quite susceptible to injury in the early seedling stage but switch grass proved very tolerant. Species of *Setaria* appeared very tolerant.

4. *Vegetable Crops:*

   Limited trials indicate pre-emergence treatment of asparagus, onions, beets, carrots, spinach, tomatoes, and potatoes to be sufficiently promising to merit further research.

5. Treatments of from one-half to ten pounds 2,4-D acid per acre resulted in moderate to complete control of all annuals including annual grasses in several states.
6. Dormant seeds were not killed by soil treatments.
7. Weed seedlings may grow uninhibited if there is insufficient rainfall to carry the 2,4-D down into the soil. They may emerge later in the season from seeds that germinate after toxicity has disappeared from the soil.
8. Smartweed, Russian thistle and field bindweed seedlings were more resistant than pigweed, lamb's-quarters, chickweed, shepherd's-purse and purslane. Some of these differences may be due to species or strain differences common to various regions.

Plantation Meetings

During January and February a schedule of meetings was conducted in cooperation with the several plantations in order to discuss present weed control practices being followed, chemicals being used experimentally and the results obtained, types of application equipment being used under the various conditions, and the entire general weed control program and its effectiveness on each plantation.

Oahu

The chemicals being used on plantations on Oahu include CADE (Concentrated Activated Diesel Emulsion) and "Penite" in dilute solution. Many experiments are being conducted with 2,4-D to determine its effectiveness as a pre-emergence soil treatment for preventing the weeds, especially grass species, from emerging. In all cases noted, good weed control resulted from as low as five pounds and less of 2,4-D per acre. The 2,4-D was applied as the ammonium salt (Honocide). On one plantation good weed control has resulted from as low as one-half and one pound of 2,4-D per acre with five pounds of the oil soluble

activator (pentachlorophenol). On the same plantation two pounds of 2,4-D have shown a marked retarding effect on the sugar cane planted immediately prior to treatment with 2,4-D. Where the cane was not treated until a month following planting, there is only slight depression of growth from five pounds of 2,4-D per acre. This would indicate that if given an opportunity to set roots before treatment with 2,4-D, the cane will be little if at all affected, whereas very dilute 2,4-D in contact with the seed piece before rooting may greatly inhibit root and shoot formation. This has been substantiated by laboratory studies in the Physiology and Biochemistry Department. It was found on another plantation that as much as 22 pounds of 2,4-D per acre did not measurably affect ratoon cane. One plantation is using the "Penite" spray entirely in plantation practice because of its relatively low cost per acre. Bermuda (manienie) grass is the most serious weed encountered on Oahu. Thus far five to seven sprays of CADE at weekly intervals have been effective in the complete eradication of this species at the Waipio Substation.

Application equipment being used on this island includes tractor-mounted broadcast equipment consisting of tank, pump, and boom; individual man-carried equipment includes either pressure tanks or knapsack sprayers with single-spray nozzles. The dilutions of chemical are applied at the rate of from 60 to 150 gallons per acre. It is at this point that some improvement may be made, both in effectiveness of chemical and in cost of application per acre, by reducing amounts of inert diluent applied. Recommendations on application equipment are made later in this report. Cost of application per acre independent of cost of chemicals is at present varying from three to five dollars per acre by individual man unit. Spraying of 2,4-D by airplane is under study at present by two plantations on Oahu. The method appears promising. A special section on airplane spraying will be found under a separate heading.

Weed species encountered in sugar-cane fields, along roadsides and irrigation ditches are as follows:

1. Bermuda grass (manienie), *Cynodon Dactylon*
2. Hairy crab grass, *Digitaria sanguinalis*
3. Violet crab grass (kukaipuaa), *Digitaria violascens*
4. Wire grass, *Eleusine indica*
5. Bristly foxtail, *Setaria geniculata*
6. Japanese rice, *Echinochloa colonum*
7. Paragrass, *Panicum barbinode*
8. Purslane, *Portulaca oleracea*
9. Nut grass, *Cyperus rotundus*
10. Wandering Jew (honohono), *Commelina nudiflora*
11. Flora's-paintbrush, *Emilia sonchifolia*
12. Joseph's-coat amaranth or Chinese spinach, *Amaranthus gangeticus*
13. Apple of Peru, *Nicandra physaloides*
14. Thyme-leaved spurge, *Euphorbia thymifolia*
15. Fuzzy rattlepod, *Crotalaria incana*
16. Wood sorrel, *Oxalis Martiana*
17. Black nightshade (popolo), *Solanum nodiflorum*
18. Castor bean, *Ricinus communis*

19. Hairy morning-glory, *Operculina Aegyptia*
20. Fiddle-leaved Poinsettia, *Poinsettia cyathorphora*
21. Rice grass, *Paspalum orbiculare*
22. Cocklebur (kikania), *Xanthium strumarium*
23. Spiny amaranth, *Amaranthus spinosus*
24. Desmanthus, *Desmanthus virgatus*

Maui

The chemicals being used for weed control on Maui include 2,4-D both as sodium and ammonium salts, Concentrate 40 and CADE. Experiments on one plantation on one field show that the use of 5 to 25 pounds of 2,4-D per acre caused no damaging effect on sugar cane when applied at the tillering stage. On the same plantation, on a low-lying field, some retardation was noted on plant cane treated with five pounds 2,4-D per acre both as spray and as dust. The greater effect on the cane was caused by the dust. On another plantation, the use of 3½ to 14 pounds of 2,4-D applied for pre-emergence gave 95 to 100 per cent control even at the lower dosage. On one plantation 10 pounds of 2,4-D dust per acre applied with a blower-type duster caused severe damage to the cane expressed as bending of the stalks at the basal nodes and general retardation of the plants.

From the experiments with 2,4-D observed on this island, one might conclude that not over five pounds 2,4-D acid per acre is needed for pre-emergence control of most of the weed species encountered. One species of *Crotalaria* and one species of *Euphorbia* appeared quite tolerant as well as nut grass (*Cyperus*) and wood sorrel (*Oxalis*). The latter two are considered of little consequence in sugar-cane fields. Experiments in the future with dosages of 2,4-D should be downward from five pounds rather than upward. The Concentrate 40 is gradually being replaced by CADE on this island. There is need for an even more effective contact chemical.

The spray equipment in use on Maui consists mainly of individual knapsack sprayers used by spray gangs. One plantation is investigating the use of a 50-foot broadcast sprayer built on a track-laying tractor. The spray gangs are being supplied either by trucks hauling the spray material from a mixing plant or the sprayers are being refilled at irrigation flumes in the field. One plantation is studying the two methods of supply. Thus far it has been determined that individuals mixing their own solution can spray approximately 1¼ acres per day as compared with 1¾ acres where the solution is hauled from a mixing plant and supplied at the field border. Even greater increase in per man-day performance is desired, since cost of application on the island is varying from $2.50 to $7.00 per acre per application. (See section on spray equipment and man-day performance.) Various types of spray booms for individual knapsack sprayers are under study at present on several plantations. One plantation is conducting extensive studies of the use of airplane spraying and has already sprayed several fields with a water slurry of 2,4-D. The main question at present regarding airplane spraying is the extent of drift. An attempt was made to study this matter. (See section on airplane spraying.) Airplane spraying has proved entirely successful in spraying for selective weed control with 2,4-D on the mainland.

Weed species encountered in sugar-cane fields, along roadsides, and along irrigation ditches include the following:

1. Bermuda grass (manienie), *Cynodon Dactylon*
2. Paragrass, *Panicum barbinode*
3. Bristly foxtail, *Setaria geniculata*
4. Japanese rice, *Echinochloa colonum*
5. Johnson grass, *Sorghum halepensis*
6. Hairy crab grass, *Digitaria sanguinalis*
7. Fuzzy rattlepod, *Crotalaria incana*
8. False koa (haole koa), *Leucaena glauca*
9. Purslane, *Portulaca oleracea*
10. Fiddle-leaved Poinsettia, *Poinsettia cyathophora*
11. Wire grass, *Eleusine indica*
12. Apple of Peru, *Nicandra Physaloides*
13. Nut grass, *Cyperus rotundus*
14. Spiny amaranth, *Amaranthus spinosus*
15. Little mallow, *Malva parviflora*

Hawaii

The chemicals in use for weed control on plantations on Hawaii include sodium and ammonium salts of 2,4-D, CADE, Concentrate 40, sodium pentachlorophenate, and sodium chlorate alone or in combination in water diluent applied as sprays. One plantation is using a combination spray of isopropyl ester of 2,4-D plus pentachlorophenol in an aromatic oil.

Because of the heavy rainfall along the Hilo and Hamakua coast areas and consequent rapid run off of water and high intake rate of water into the soil, there is great need for a chemical herbicide that is retained in the soil against leaching. The possibilities of the use of 2,4-D in oil solution or emulsion are being investigated for this reason. There is a possibility that 2,4-D in the oil solution or in the oil phase of an emulsion, when applied to the soil for pre-emergence weed control, will be retained on the soil particles perhaps by adsorption and continue to be toxic to germinating weed seedlings over a longer period of time than where the 2,4-D is applied in water.

From experiments and plantation practices on several plantations, it was evident that soil treatments with sodium pentachlorophenate and to some extent with dilute solutions of sodium chlorate gave varying degrees of pre-emergence control of weeds including the various shallow-rooted grasses. It is logical to expect that the presence of certain concentrations of herbicidal chemicals in the soil solution adjacent to or in contact with germinating seeds and tender seedlings will cause the inhibition of growth of those seedlings. The pre-emergence control of weeds by chemicals other than 2,4-D also needs considerable investigation. It is commendable that representatives of the various plantations have already met with Experiment Station staff members to plan uniform experiments with the various chemicals to be conducted on several plantations on Hawaii. Similar uniform experiments should be started on the other islands as well.

The application equipment in use on Hawaii at present includes the following: (1) Tractor-mounted broadcast sprayers treating up to 45 acres per day. (2)

tractor-trailed spray units with individually carried hose lines and single nozzle guns, treating 10 to 15 acres per day; (3) tractor-mounted interline sprayers with short spray booms between the rows, set low enough to spray the weeds at the base of the sugar-cane plants. These units will spray from 15 to 20 acres per day; (4) both portable and stationary pumping units with primary and secondary hose lines delivering the solution to individually carried guns with single nozzles. With this system each individual covers from approximately ¾ acre per day in heavy weeds to approximately 2 acres per day where weed cover is light; (5) individually carried knapsack sprayers with single-nozzle guns. Individual units are covering from ½ acre to approximately 2 acres per day; and (6) some cultivation for weed control is also practiced.

In practically all cases the high-volume, cone-type nozzles were in use and rates of treatment varied from 35 gallons per acre to approximately 300 gallons per acre. It is suggested that the per man-day performance can be greatly increased with the use of low-volume, flat, fan-type nozzles and interline booms for both pumping station units and knapsackers. (See sections on spray equipment and per man-day performance.)

Several pernicious weed species were encountered on Hawaii including *Cynodon Dactylon*, *Panicum repens*, *Panicum barbinode*, *Paspalum conjugatum*, *Sorghum halepensis*, *Commelina nudiflora*, *and Tritonia Crocosmaeflora*. It appears that these species are to some extent being spread by cultivation equipment.

The best kill of *Panicum repens* observed was on one plantation where 750 to 800 pounds of dry sodium chlorate per acre had been applied seven months previously. No new growth was evident at the time of observation. There was one report of satisfactory kill of *Tritonia Crocosmaeflora* from one treatment of 12 pounds ammonium salt of 2,4-D per acre.

It is suggested that repeated treatments of a contact herbicide such as CADE plus 2,4-D of the ester type be tried on the above species. Treatments should be repeated about four to seven days after new growth has started. The principle involved is that of gradual reduction of stored carbohydrates in the root resulting in eventual destruction of the plant. Many treatments may be needed and cost may become fairly high. It seems logical that the cost of special weed control of this sort should not be charged against the present crop, but should be charged against several crops in future years as permanent improvement of the land. This system of weed control by repeated cultivation has been successful against deeply rooted perennial weeds such as *Convolvulus arvensis* and *Lepidium draba* in the North Central States. Also against *Agropyron repens*, a serious perennial grass.

Weed species encountered in sugar-cane fields, along roadsides and along irrigation ditches and cane flumes are as follows:

1. Paragrass, *Panicum barbinode*
2. Torpedo panicum, *Panicum repens*
3. Hairy crab grass, *Digitaria sanguinalis*
4. Wire grass, *Eleusine indica*
5. Foxtail, *Setaria sp.*
6. Bermuda grass (manienie), *Cynodon Dactylon*
7. Hilo grass, *Paspalum conjugatum*

8. Johnson grass, *Sorghum halepensis*
9. Japanese rice, *Echinochloa colonum*
10. Bristly foxtail, *Setaria geniculata*
11. Red top, *Tricholaena rosea*
12. Guinea grass, *Panicum maximum*
13. Flora's-paintbrush, *Emilia sonchifolia*
14. Spanish needle, *Bidens pilosa*
15. Wood sorrel, *Oxalis Martiana*
16. Castor bean, *Ricinus communis*
17. Apple of Peru, *Nicandra physaloides*
18. Wandering Jew (hononono), *Commelina nudiflora*
19. Purslane, *Portulaca oleracea*
20. Spanish clover, *Desmodium uncinatum*
21. Curled dock, *Rumex crispus*
22. Annual sow thistle (pualele), *Sonchus oleraceus*
23. Rhodes grass, *Chloris gayana*
24. Black nightshade, *Solanum nodiflorum*
25. Tropic Ageratum, *Ageratum conyzoides*
26. Spiny amaranth, *Amaranthus spinosus*
27. Tritonia lily, *Tritonia Crocosmaeflora*
28. Tarweed, *Cuphea Balsamona*
29. Fuzzy rattlepod, *Crotalaria incana*
30. Richardsonia, *Richardsonia sp.*
31. Nut grass, *Cyperus rotundus*
32. Mint, *Mentha sp.*

Kauai

The chemical herbicides in use for weed control on Kauai include 2,4-D, CADE, and Concentrate 40. Varying dosages of 2,4-D have been applied up to 10 pounds per acre as plantation practice and up to 20 pounds per acre experimentally. Experiments were also observed where as low as 1/16 pound per acre of 2,4-D was applied in the water with each irrigation. The only observed case of serious damage to sugar cane from 2,4-D was on one plantation where 15 pounds 2,4-D acid per acre had been applied with an orchard blower duster six months previously. Damage in this case was expressed as brittleness and bending of the stalks, particularly at the lower nodes, poor color, and a collar of root stubs around the lower nodes. Scattered plants of seedling cane were found in one field that showed some effect of 2,4-D at 8 and 10 pounds per acre applied as a spray. Experiments with 2,4-D applied as sodium salt in water spray showed the following results on one plantation:

lbs. 2,4-D per acre	Herbicidal index	Time following treatment
2½	*4 (85 to 95% control)	3 months
5	5 (95 to 100% control)	" "
10	5	" "
15	5	" "
20	5	" "

*Black nightshade was the predominating species remaining on this plot. There appeared to be a longer period of weed control from five pounds per acre than from 2½ pounds.

Experiments on another plantation indicated that effective weed control had been accomplished under the conditions of that experiment by applying 1/4, 1/8, or 1/16 pound of 2,4-D in the irrigation water. In one plot 1/8 pound of 2,4-D as the pure acid applied in eight successive irrigations (total of one pound per acre) had resulted in effective weed control which was graded as index 5 (95 to 100% control). Some wire grass and some nut grass remained. Weed control over the ridge between the lines (kuakua) was not accomplished by this method.

Methods of application on Kauai include:

1. Tractor-mounted broadcast spray equipment.
2. Tractor-mounted interline sprayers including sled-mounted interline sprayers that ride on the ridge.
3. Individually carried pressure-tank sprayers.
4. Individually carried knapsack sprayers.
5. One horse-drawn interline sprayer was also observed.

The lowest volume of application observed was at 15 gallons per acre in the application of CADE at the concentration of 1-8. Two nozzles per individual were carried and the men were travelling approximately three miles per hour. Coverage appeared satisfactory. The per man-day performance on field scale was approximately five acres. The spray emulsion was supplied to the spray gang at the field border through a special measuring device for five gallons per filling. Pressure was supplied by an air compressor attached to the truck for one gang and by a portable compressor for another gang. This was the best illustration observed where man-day performance was increased and cost of application reduced by the use of a multiple-nozzle boom.

The most pernicious weeds on this island included Bermuda grass and some Johnson grass. Suggestions were made to the plantations for the use of repeated sprays of a contact herbicide such as CADE for the gradual reduction and elimination of Bermuda grass. One plantation reported good results with the use of 2,4-D dust against this species on the irrigation ditch banks. Another plantation has had good results in the control of Johnson grass with repeated sprays of 8 pounds 2,4-D sodium salt plus 20 pounds sodium pentachlorophenate plus wetting agent in a wetting spray on the acre basis.

Weed species encountered in sugar-cane fields, along roadsides and irrigation ditches:

1. Bermuda grass, (manienie), *Cynodon Dactylon*
2. Johnson grass, *Sorghum halepensis*
3. Sensitive plant (hila hila), *Mimosa pudica*
4. Cinquefoil, *Potentilla sp.*
5. Spanish clover, *Desmodium uncinatum*
6. Small Crotalaria, *Crotalaria sp.*
7. Nut grass, *Cyperus rotundus*
8. Black nightshade (popolo), *Solanum nodiflorum*
9. Annual sow thistle (pualele), *Sonchus oleraceus*
10. Purslane, *Portulaca oleracea*
11. Bristly foxtail, *Setaria geniculata*
12. Wire grass, *Eleusine indica*
13. Flora's-paint bursh, *Emilia sonchifolia*

14. Spiny amaranth, *Amaranthus spinosus*
15. Fuzzy rattlepod, *Crotalaria incana*
16. Various leaf spurge, *Euphorbia sp.*
17. Richardsonia, *Richardsonia sp.*
18. Thyme-leaved spurge, *Euphorbia thymifolia*
19. Japanese rice, *Echinochloa colonum*
20. Tropic Ageratum, *Ageratum conyzoides*
21. Apple of Peru, *Nicandra Physaloides*
22. Jimson weed, *Datura stramonium*
23. Plush grass, *Chloris sp.*
24. Sand bur, *Cenchrus echinatus*
25. Sweet clover, *Melilotus alba*
26. Bur clover, *Trifolium sp.*

Experiment Station Investigations

Cooperative Program of Research

The cooperative program of fundamental studies on herbicides carried on by this Station is very commendable. The Station is in good position to gain information rapidly and accurately because of the integration of research including formulation of herbicides by the Chemistry Department and study of physiological aspects of the use of these formulations both on sugar cane and weeds by the Physiology and Biochemistry Department. Studies of the effect of 2,4-D on soil microorganisms are getting under way in the Pathology Department. The program of testing the effectiveness of the various herbicides and working out the practices to be used on plantations is conducted by the Agronomy Department. Active cooperation in the development of application equipment was received from the Agricultural Engineering Department during the course of some of the special studies carried on here regarding the equipment shown in the pictures to follow. Parasites introduced by the entomologists are taking a toll of cactus in many areas. This is a very interesting development and should be further investigated for the possibilities of biological control of other weed species either by insects or diseases. The Island Representatives of the Experiment Station are also closely cooperating in this program in extending the information to the plantations. No other case is known, with the possible exception of the United States Department of Agriculture, where such an extensive integrated program of research in weed control is being conducted at the present time.

With this cooperative program of research so well organized in the Experiment Station, it is unfortunate that there is rather a confused attitude and complete lack of uniformity in weed control practices on the several plantations. It is recognized, of course, that 2,4-D has recently and is at present showing excellent results in the control of weeds, including grasses, by soil treatments for inhibiting the growth of seedlings before they emerge. The 2,4-D in combination with chlorinated phenols is showing considerable promise with possibly greater effectiveness than 2,4-D alone in water or in oil diluent. The 2,4-D esters in oil have shown some possibility of longer retention in the soil than 2,4-D in water diluent. All of these new developments have come over a short period of time, and there has been little conclusive information with which to supply the answers to the many questions that naturally arise regarding new chemicals and prac-

tices. This is the main reason for the dynamic and non-uniform weed control program on plantations at present. In most cases plantation personnel are actively cooperating in obtaining the information needed under their conditions.

It is suggested for the future that four steps be followed in the development and final use of new herbicides, which will ensure sufficient testing and information regarding use before recommendation to plantations. These are as follows:

1. *Formulation of chemicals and chemical combinations that have herbicidal value:* This formulating would be done by the Chemistry Department.
2. *Screening:* Standard testing practices should be organized to which all chemicals or chemical combinations be subjected regarding physiological aspects on crop and weeds, soil organism reaction, and herbicidal index. This screening would eliminate all but those chemicals which were most effective on weeds and least damaging to sugar cane, before being placed in field tests. This would be a program of fundamental studies.
3. *Development and Testing:* Grade A field tests and some observation tests should be run on all promising new herbicides that have carried through the screening process. These should be tests of dosages, rates of diluent, and involve only a few chemicals. The tests should be well replicated, to determine whether the same combination will react the same several times under the same set of conditions. Dosages of the active chemicals in pounds per acre and rate of inert diluent in gallons or pounds per acre should be studied in separate tests. Methods of application should be worked out in the testing stage. These tests should be conducted on as many plantations simultaneously as will cooperate in the program.
4. *Recommendation to Plantations:* After adequate tests have shown the value or lack thereof of any chemical or combination and application methods have been worked out, full information regarding recommendations should be provided to each plantation simultaneously on which the herbicide has proved acceptable.

The above steps of development are suggested as an orderly program of development and recommendation of new herbicides which would fully utilize the integrated program of research under way at present. It would reduce the time spent in field testing, especially be plantation personnel, and would ensure adequate evaluation of a new material, and prevent too hasty discard of its use.

Special Studies

During the last three months a few studies have been conducted regarding some newer chemicals and application methods. It has been impossible in this time to complete the studies and draw logical conclusions, but some information will be given here as a progress report to indicate what has been undertaken and also to present the techniques followed as a guide to completion of these studies and further investigation of the same nature.

Chemicals. On all islands visited during plantation meetings, Bermuda grass (manienie) was the most important weed species. Consequently, this species was selected for testing to check the effectiveness of several new chemicals on grasses. The chemicals used are shown in Tables I and II. The dosages of chemical and rates of diluent are given as well as dates treated and the control index.

TABLE I

CONTROL OF MANIENIE GRASS

Pot No.	Chemical	Lbs./ acre	G.P.A.	Diluent	Grams/ 25 c.c.	Date Treated 2/17/48	Date Treated 2/27/48	Date Treated 3/8/48	Control Index 2/27/48	Control Index 3/8/48	Control Index 3/18/48
1	Ammonium Tri-	10	50	Water	.594	"	"	"	1	1	1
2	Chloro acetate	"	"	"	"	"	"	"	1	1	1
3	"	"	"	"	"	"	"	"	1	1	1
4	Sodium Tri-	10	50	Water	.594	"	"	"	1	1	1
5	Chloro acetate	"	"	"	"	"	"	"	1	1	1
6	"	"	"	"	"	"	"	"	1	1	1
7	ATCA	20	50	Water	1.21	"	"	"	1	1	2
8	"	"	"	"	"	"	"	"	1	1	2
9	"	"	"	"	"	"	"	"	1	1	2
10	STCA	20	50	Water	1.21	"	"	"	1	1	1
11	"	"	"	"	"	"	"	"	1	1	1
12	"	"	"	"	"	"	"	"	1	1	1
13	ATCA	40	50	Water	2.42	"	"	"	1	2	3
14	"	"	"	"	"	"	"	"	1	2	3
15	"	"	"	"	"	"	"	"	1	2	3
16	STCA	40	50	Water	2.42	"	"	"	1	2	3
17	"	"	"	"	"	"	"	"	1	2	3
18	"	"	"	"	"	"	"	"	1	2	3
19	ATCA	60	50	Water	3.63	"	"	"	2	4	5
20	"	"	"	"	"	"	"	"	2	4	5
21	"	"	"	"	"	"	"	"	2	4	5
22	STCA	60	50	Water	3.63	"	"	"	2	4	5
23	"	"	"	"	"	"	"	"	2	4	5
24	"	"	"	"	"	"	"	"	2	4	5

TABLE I (Continued)

CONTROL OF MANIENIE GRASS

Pot No.	Chemical	Lbs./ acre	G.P.A.	Diluent	Grams/ 25 c.c.	Date treated 2/17/48	Date treated 2/27/48	Date treated 3/8/48	Control Index 2/27/48	Control Index 3/8/48	Control Index 3/18/48
25	CADE	1–8	50	Water	10 CADE	"	"	"	1	1	1
26	"	"	"	"	5 SSA	"	"	"	1	1	1
27	"	"	"	"	65 Water	"	"	"	1	1	1
28	Hi Vol 2–2½	1–5	50	Diesel		"	"	"	2	2	2
29	"	"	"	"	5 c.c.	"	"	"	2	2	2
30	"	"	"	"	20 c.c. Diesel	"	"	"	2	2	2
31	Check	0	0	—	—				—	—	—
32	"	0	0	—	—				—	—	—
33	"	0	0	—	—				—	—	—
34	ATCA	40	200	Water	2.42	"	"	"	1	4	5
35	STCA	40	200	Water	2.42	"	"	"	1	3	5
36	ATCA	80	200	Water	4.84	"	"	"	2	4	5
37	STCA	80	"	"	4.84	"	"	"	2	4	5
38	ATCA	160	"	"	7.26	"	"	"	2	4	5
39	STCA	160	"	"	7.26	"	"	"	2	4	5
40	ATCA	240	"	"	9.68	"	"	"	3	5	5
41	STCA	240	"	"	9.68	"	"	"	3	5	5
42	CADE	1–8	"	"	As above	"	"	"	1	2	2
43	Hi Vol	1–5	"	Diesel	As above	"	"	"	3	2	2
44	Check	0	0	—	—				—	—	—

Index 1–Less than 50%
" 2–50–70%
" 3–70–85%
" 4–85–95%
" 5–95–100%

On perennials this means top growth kill.

TABLE II

CONTROL OF MANIENIE GRASS

Pot No.	Chemical	Lbs./ acre	G.P.A.	Diluent	C*	S*	2, 7-R W.A.	c.c. or gms./ 25 c.c. Diluent		Date treated 3/12/48	Date treated 3/24/48	Control Index 3/22/48
115	Ammonium Tri-	40	50	Water	x		1%	2.42 gms.		"	"	2
116	Chloro acetate	"	"	"	x		"	"		"	"	2
117	ATCA	40	100	Water	x		1%	1.21 gms.		"	"	2
118	"	"	"	"	x		"	"		"	"	2
119	ATCA	40	100	Water		x	1%	1.21 gms.		"	"	1
120	"	"	"	"		x	"	"		"	"	1
121	ATCA	60	50	Water	x		1%	3.63 gms.		"	"	2
122	"	"	"	"	x		"	"		"	"	2
123	ATCA	60	100	Water	x		1%	1.81 gms.		"	"	2
124	"	"	"	"	x		"	"		"	"	2
125	ATCA	60	100	Water		x	1%	1.81 gms.		"	"	1
126	"	"	"	"		x	"	"		"	"	1
127	Sodium Tri-	40	50	Water	x		1%	2.42 gms.		"	"	2
128	Chloro acetate	"	"	"	x		"	"		"	"	2
129	STCA	40	100	Water	x		1%	1.27 gms.		"	"	2
130	"	"	"	"	x		"	"		"	"	2
131	STCA	40	100	Water		x	1%	1.21 gms.		"	"	1
132	"	"	"	"		x	"			"	"	1
133	STCA	60	50	Water	x			1%	3.63 gms.	"	"	2
134	"	"	"	"	x			"	"	"	"	2
135	STCA	60	100	Water	x			1%	1.81 gms.	"	"	2
136	"	"	"	"	x			"	"	"	"	2
137	STCA	60	100	Water		x		1%	1.81 gms.	"	"	1
138	"	"	"	"		x		"	"	"	"	1
139	Trichloro acetic acid	40	100	4060-0	x			0	0.8 gms.	"	"	5
140	Trichloro acetic acid Sp. Gr.=1.57	"	"	"	x			"	"	"	"	5

TABLE II (Continued)

Pot No.	Chemical	Lbs./acre	G.P.A.	Diluent	C*	S*	2, 7-R W.A.	c.c. or gms./25 c.c. Diluent	Date treated 3/12/48	Date treated 3/24/48	Control Index 3/22/48
141	Herbicide 919s	40**	100	Water	x		1%	2.1 gms.	"	"	2
142	" "	"	"	"	x		"	"	"	"	2
143	Chlorophenyl	10	100	Diesel	x		0	0.25 c.c.	"	"	3
144	Allyl Carbonate	"	"	"	x		"	"	"	"	3
145	CAC	20	100	Diesel	x		0	0.5 c.c.	"	"	4
146	CAC (Sp. Gr.=1.18)	"	"	"	x		"	"	"	"	4
147	CAC	40	100	Diesel	x		0	1.0 c.c.	"	"	4
148	"	"	"	"	x		"	"	"	"	4
149	Sodium Isopropyl	10	100		x		1%	.30 c.c.	"	"	1
150	Zanthate	"	"		x		"	"	"	"	1
151	SIZ	20	100		x		1%	.60 c.c.	"	"	1+
152	"	"	"		x		"	"	"	"	1+
153	SIZ	40	100		x		1%	1.21 c.c.	"	"	1+
154	"	"	"		x		"	"	"	"	1+
155	High Vol.	1–5	100	Diesel	x		0	1 to 4	"	"	5
156	" "	"	"	"	x		"	"	"	"	5
157	CADE	1–5	100	Water	x		0	10 CADE, 5 SSA, 35 Water	"	"	3
158	"	"	"	"	x		"		"	"	3
159	Aromatic Oil	pure	100	—	x		0	pure	"	"	4
160	" " 4060-0	"	"	—	x		"	"	"	"	4
161	Check	0	0	—	—	—	—	—			—
162	"	"	"	—	—	—	—	—			—

Index 1–less than 50%
" 2–50–70%
" 3–70–85%
" 4–85–95%
" 5–95–100%

On perennials this means top growth kill.

*C=Contact
S=Soil treatment
**52.5% Active

The tables are self-explanatory and no attempt will be made here to draw conclusions except to point out that 40 and 60 pounds of either ammonium or sodium trichloroacetate have shown considerable promise for the comtrol of Bermuda grass grown in pots when used in repeated treatments. No information is available regarding price schedules of either of these chemicals. Consequently, it is not known whether their use would be economically practicable. Some of the other chemicals have also shown some promise. The effects of ammonium and sodium trichloroacetate on Bermuda grass at 10, 20, 40 and 60 pounds per acre in 50 gallons of water applied three times at 10-day intervals are illustrated in Fig. 1. The index is given on the first page of Table I.

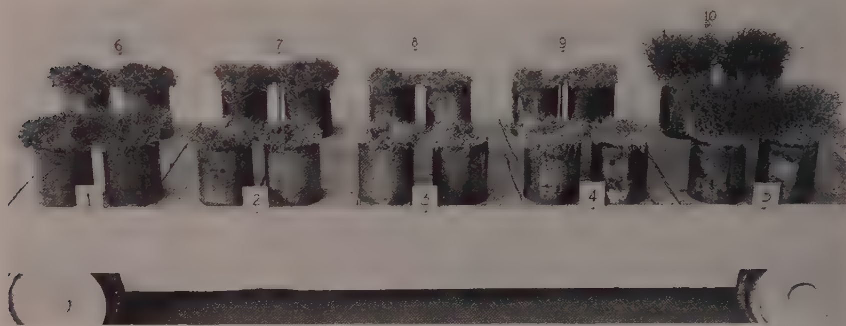


Fig. 1. Effect of ammonium (ATCA) and sodium (STCA) trichloroacetate on Bermuda (manienie) grass. These treatments at 10-day intervals.

1. ATCA 10 lbs. in 50 g.p.a. water	6. STCA 10 lbs. in 50 g.p.a. water
2. " 20 " " " " "	7. " 20 " " " " "
3. " 40 " " " " "	8. " 40 " " " " "
4. " 60 " " " " "	9. " 60 " " " " "
5. Check	10. Check

It should be pointed out that there has long been need for an adequate system of grading the results of weed control tests without the laborious task of counting individual plants. The following index system of grading was worked out in cooperation with H. A. Alexander and Peter Kim. This index system is based on visual estimate of percentage reduction in weed population as compared with check plots. The system can also take into account reduced vigor of remaining plants to evaluate where actual stand is counted. It has the further advantage of classifying differences on a broad percentage basis, thus making estimates quick and fairly accurate. The data can also be analyzed statistically with reduced bias. The index system is as follows:

Index	Per Cent Reduction of Weeds in Stand and Vigor
1	less than 50 per cent
2	50 to 70 per cent
3	70 to 85 per cent
4	85 to 95 per cent
5	95 to 100 per cent

This system of grading recognizes the fact that the lower percentages of reduction are of little consequence in practical weed control. Therefore, close differences

are measured only at the higher percentages. A chemical must result in 95 to 100 per cent control to be given a top rating. This system of grading was used in the above study on Bermuda grass.

Rates of treatment per acre: Recent studies on the mainland, many of which will be reported in the 1947 Proceedings of the North Central Weed Control Conference, have shown that reduced rates of diluent as low as 2½ and 5 gallons per acre by ground equipment and as low as ¼ to 5 gallons per acre by airplane have effectively covered the desired area when properly applied. It is recognized in this regard that in a water spray the water is inert and its use is only for the uniform spread of a given amount of chemical over a unit area. Where an oil diluent is used, it is a part of the active material.

In determining the amount of spray to be applied one should first determine the type of control desired and the conditions of the weeds as follows:

1. *Pre-emergence control:* 2,4-D alone or in combination would be used in this case. The amount of water diluent need be only great enough to ensure uniform coverage of the soil surface. Five to 25 gallons per acre should be sufficient. It should be remembered that the same amount of active chemical be applied per acre whether in 5 or 100 gallons of water per acre.
2. *Selective post-emergence control of broad-leaved species or woody plants:* The 2,4-D alone or in combination in either water, oil or emulsion diluent would be applied in this case. A uniform pattern of spray droplets over the foliage would be sufficient for active control, inasmuch as the 2,4-D is translocated in the plant. The amount of diluent is dependent on density of foliage. From 25 to 100 gallons per acre should be sufficient whether water, oil or emulsion. The 2,4-D esters have proved the most effective on woody plants.
3. *Complete post-emergence control of all weeds:* A contact herbicide with or without 2,4-D in combination would be used in this case. Enough spray is needed either with water or oil diluent to completely cover the foliage of the plants being sprayed. Heavy stands of Bermuda grass have required 125 gallons per acre for complete coverage. Rate of diluent is dependent on foliage present. As low as 10 gallons per acre of oil diluent have given complete coverage on small plants, but with ground equipment, from 25 to as high as 200 or 300 gallons per acre may be needed.

It is suggested for pre-emergence control that 25 gallons per acre by ground equipment be standard until further testing shows that a lesser amount can be used under the conditions on each plantation. This same amount could also be used both for selective post-emergence spraying and complete post-emergence control when weeds are small. (Refer to the section on Calibration of Spray Equipment for recommendations.)

Spray Equipment: Ground spray equipment being used at the present time on plantations includes the following:

1. Tractor-mounted broadcast and interline sprayers.
2. Tractor-trailed sprayers with booms for broadcast spraying or hose lines and single-nozzle guns carried by individual men or women.

3. Pumping stations with individual hose lines and single-nozzle guns.
4. Individual pressure tanks supplied in the field or at the field border. Pressure is supplied by air compressors or by filling tanks against an initial pressure of 25 pounds building it to 100 pounds. The spray is delivered in most cases through one nozzle per unit.
5. Individual knapsack sprayers that are pumped by the carrier and dispersing spray from one nozzle.

The first three type units are most common on the unirrigated plantations. The latter two are most common on the irrigated plantations. At present the possibilities of use of tractor-mounted, broadcast and interline sprayers on irrigated fields are being investigated. Two plantations on Oahu, one on Maui, and two on Kauai are attempting the use of tractors on ridges between the irrigated cane rows. The track-laying tractors appear to be more satisfactory for this purpose.

The long track tractors with 45 to 50 foot booms are being tried travelling at right angles to the cane lines and as nearly as possible parallel to the irrigation flumes. Where observed, these units are well built and are excellent spray outfits, but in travelling across the tops of the ridges, there is considerable whip of the long booms and resultant non-uniformity in application especially where the nozzles are attached at the ends of hoses below the boom. There is little opportunity to travel at a speed greater than 1½ to 2 miles per hour and often the speed must be reduced in crossing level ditches again causing non-uniformity of spray.

It is suggested that a method of bridging of the irrigation flume or removal of portions thereof be investigated to make possible the travel of the tractors on top of the ridges between rows and parallel to the rows. This would cause much less whip of the boom and more uniform application.

It is also suggested that smaller tractors of the D-2 or DC-22 types be used and four interline booms be suspended from a beam across the rear with the proper spacing for the rows. Each interline boom should have three or four fan-shaped spray nozzles such as the "Teejet" or "Monarch". The four booms should be suspended independently and be raised independently by hydraulic pumps. The individual boom mounting would be supported toward the rear from the overall beam and at the rear end on a short metal ski running on the ground between the rows. Each boom should be adjustable for height and would be raised by the hydraulic pumps when turning at ends of the rows.

This system would, by adjustment, be used both for broadcast and interline spraying. With whip at the ends of the boom reduced to a minimum, the unit forward speed could be increased to four or five miles per hour, traveling between the lines and over or through irrigation flumes or turn at the flume.

Man-Day Performance: In Figs. 2 to 10, single and multiple man sprayers are illustrated with which per man-day performance can be greatly increased over the use of the single-nozzle gun being used at present. Table III and Fig. 11 show the per man-day performance in spraying weeds where different widths of spray are used at different speeds of travel and at different percentages of actual spraying time per day. It is worthy of note that as width of spray is increased from one foot to five feet at 2½ miles per hour travel, and at 50 per

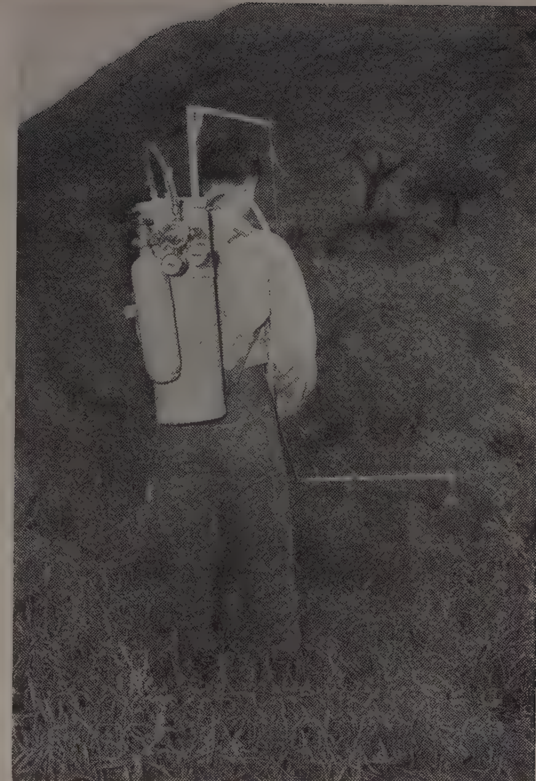


Fig. 2. Pressure tank sprayer with high-pressure cartridge. a. Suspended spray boom with "Teejet" nozzles spaced 15 inches apart. b. Overhead pole attached to back plate. A shock-absorbing rubber band or light spring will eliminate rising and falling of the boom when walking. c. Regular pump-up pressure spray tank with the pump inactivated. d. Pressure cartridge with compressed nitrogen at 1800 pounds per square-inch pressure. This amount of compressed nitrogen is sufficient to disperse 15 gallons of spray when regulated to 30 pounds working pressure. Cartridge readily detached and exchanged.

Fig. 3. Rear view of pressure tank sprayer with high-pressure cartridge. This shows the arrangement of the cartridge and pressure regulator. Note large back plate for comfort in carrying the unit. Shoulder straps can be padded with sponge rubber.

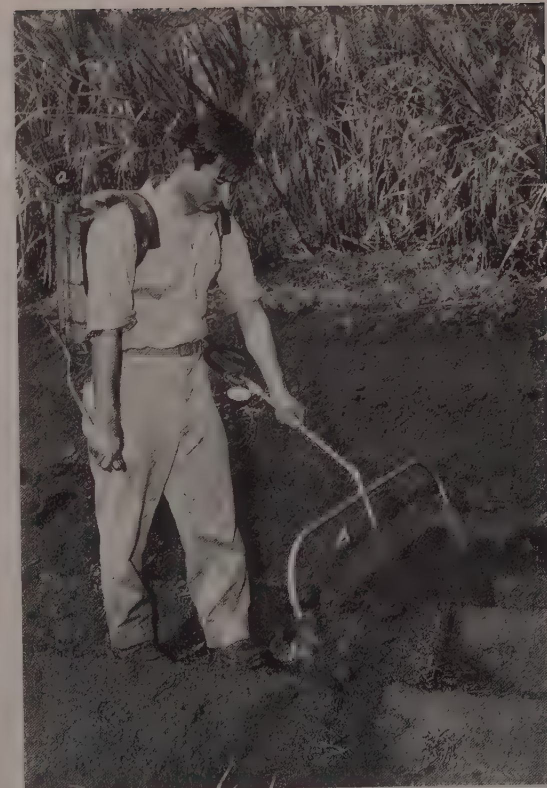


Fig. 4. Pressure tank sprayer with pressure regulator and three-nozzle interline boom. a. Pressure tank with filler opening and air valve at the top. 100 pounds pressure. b. Pressure regulator keeps pressure constant at desired working pressure. Should be set at 30 pounds. c. Interline spray boom with three "Teejet" nozzles. Ends of the boom are 4 inches lower than center in order to spray the ridge and banks with a minimum of drift of spray. Total length of the boom is 36 inches. Nozzles spaced 18 inches.

Fig. 5. Knapsack sprayer and three-nozzle interline boom. a. Regular knapsack spraytank and pump. b. Interline spray boom with pressure gauge and three "Teejet" nozzles. Three nozzles each delivering 0.2 gallon per minute is the top capacity of this pump at pressures varying from 20 to 30 pounds per stroke. Additional nozzles can be added only if the orifice size of each is reduced until total delivery per minute does not exceed 0.6 gallon. Nozzles are spaced 18 inches apart making the total length of the boom 36 inches.

Fig. 6. Three-line individual spray unit operated off pressure tank. Boom supported by pole attached to the pressure tank. Pulley at the end of the pole makes regulation of height at the ends of the boom easily adjustable. The nozzles between lines are spaced 18 inches apart with 30-inch spacing across the line where lines are spaced 5½ feet apart and 24 inches across the line where lines are 5 feet apart. Boom is built of ⅝-inch conduit tubing with one-half of ¼-inch couplings brazed on to attach the nozzles. Total weight of unit with 5 gallons of water is 77 pounds. This unit can be readily handled and is not considered too heavy, but is cumbersome to remove to be refilled. At 20 gallons per acre, ¼ acre could be sprayed with one filling.

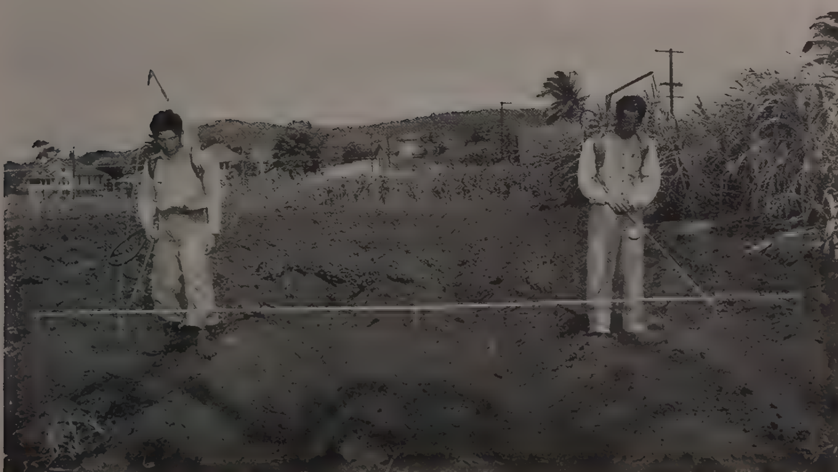
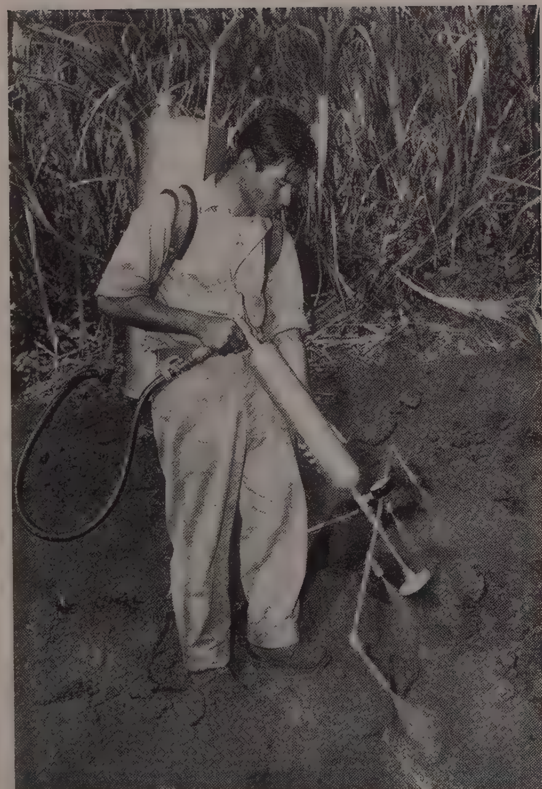


Fig. 7. Two-man broadcast sprayer. Boom is made from ⅝-inch light conduit. Nozzles are spaced 18 inches apart between the rows, 30 inches apart across the rows for 5½ feet row spacings, and 24 inches apart across the row for 5-foot row spacings. Such a boom may be adapted for use with a hose line from a pumping unit and attached to one end of the boom.



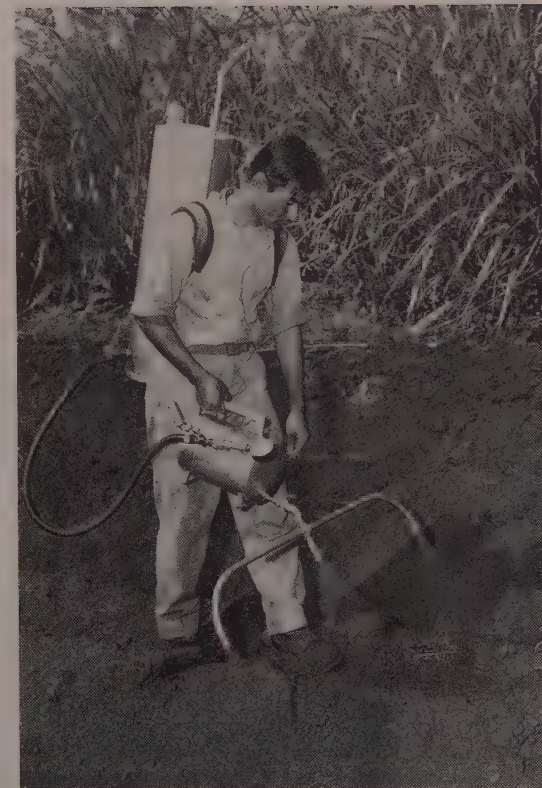


Fig. 8. Pressure tank and auxiliary tank for spraying experimental plots. Air pressure is carried in main tank and regulated to 30 pounds or other desired pressure. Experimental chemical is carried in and dispersed from the auxiliary tank. Liquid can be measured exactly for the area to be treated or amount can be measured before and after spraying in order to determine amount sprayed. Main feature is complete dispersal of the liquid. Filling is accomplished by removing the plug at the upper end. Circular plate at the lower end is for resting the unit on during filling to keep the nozzles out of the soil. Both pressure and spraying are controlled by ¼-turn shutoff cocks. Nozzle spacing 15 inches.

Fig. 9. Pressure tank and auxiliary tank for small quantities of liquid used in spraying experimental plots. The pressure tank is used for air only in this case. The liquid is delivered from the auxiliary tank. This unit was built from a discarded weed burner. The main feature is complete exhaustion of the desired amount of liquid per unit area. All of the liquid can be dispersed where pipe is attached at lower end of tank to the surface only and is not run through and up inside.

Fig. 10. Individual plant or pot sprayer. Plant is passed under the spray at calibrated rate of speed that sprayer would pass over the plants in the field. a. Pressure cylinder holding experimental spray liquid. b. Pressure regulator changing pressure from 150 p.s.i. in the hose line to 30 p.s.i. working pressure. c. Pressure gauge, shutoff cock, and flat atomizing spray nozzle with replaceable tip. d. Plant carried on platform on roller skate at designated number of inches per second.

cent actual spraying time, the per man-day performance increases from 1.21 to 6.06 acres sprayed per day. This can most nearly be accomplished by changing from a one-nozzle gun to a three-or-four nozzle boom covering the distance

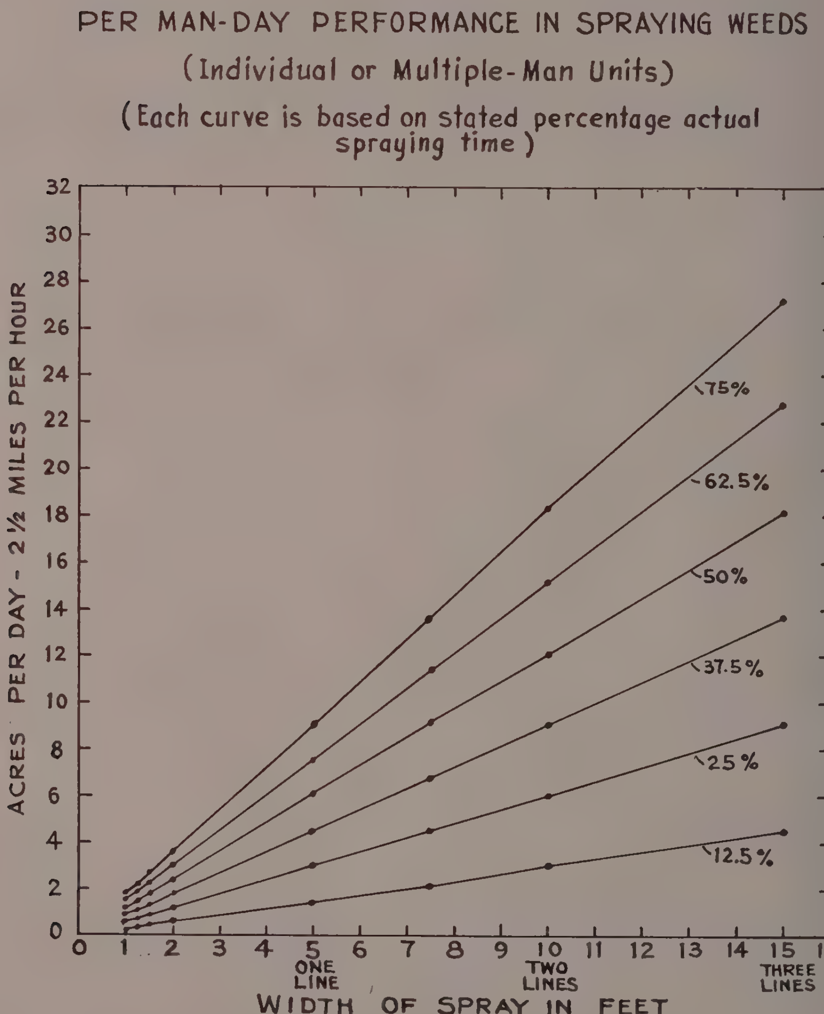


Fig. 11.

between rows. One plantation has found that the actual spraying time of their men varies from 25 to 50 per cent. Another plantation has found that, by changing their supply system, actual spraying time has been increased to nearly 75 per cent.

TABLE III

PER MAN-DAY PERFORMANCE OF INDIVIDUAL OR MULTIPLE-MAN SPRAYING UNITS

(Based on 5-foot line spacing)

Walking Speed M.P.H.	Width of spray in feet	No. of Nozzles	Type of Nozzles	Acres treated—Actual spraying time per day 1 hour Acres	2 hours Acres	3 hours Acres	4 hours Acres	5 hours Acres	6 hours Acres
1	1.0*	1	Cone	.12	.24	.36	.48	.61	.73
"	1.25	1	Cone	.15	.20	.45	.61	.76	.91
"	1.5	1	Fan	.18	.36	.55	.73	.91	1.09
"	2.0	1	Fan	.24	.48	.73	.97	1.21	1.45
"	5.0	3	Fan	.61	1.21	1.82	2.42	3.03	3.64
"	7.5	4.5	Fan	.91	1.82	2.73	3.64	4.55	5.45
"	10.0	6	Fan	1.21	2.42	3.64	4.85	6.06	7.27
"	10.0	9	Fan	1.82	3.64	5.45	7.27	9.09	10.91
2	1.0	1	Cone	.24	.48	.73	.97	1.21	1.45
"	1.25	1	"	.30	.61	.91	1.21	1.52	1.82
"	1.50	1	Fan	.36	.73	1.09	1.45	1.82	2.18
"	2.0	1	"	.48	.97	1.45	1.94	2.42	3.91
"	5.0	3	"	1.21	2.42	3.64	4.85	6.06	7.27
"	7.5	4.5	"	1.82	3.64	5.45	7.27	9.09	10.91
"	10.0	6	"	2.42	4.85	7.27	9.70	12.12	14.55
"	15.0	9	"	3.64	7.27	10.91	14.55	18.18	21.82
2½	1.0	1	Cone	.30	.61	.91	1.21	1.52	1.82
"	1.25	1	"	.38	.76	1.14	1.52	1.89	2.27
"	1.50	1	Fan	.45	.91	1.36	1.82	2.27	2.73
"	2.0	1	"	.61	1.21	1.82	2.42	3.03	3.64
"	5.0	3	"	1.52	3.03	4.55	6.06	7.58	9.09
"	7.5	4.5	"	2.27	4.55	6.82	9.09	11.36	13.64
"	10.0	6	"	3.03	6.06	9.09	12.12	15.15	18.18
"	15.0	9	"	4.55	9.09	13.64	18.18	22.72	27.27
3	1.0	1	Cone	.36	.73	1.09	1.45	1.82	2.18
"	1.25	1	"	.45	.91	1.36	1.82	2.27	2.73
"	1.50	1	Fan	.55	1.09	1.64	2.18	2.73	3.27
"	2.0	1	"	.73	1.45	2.18	2.91	3.64	4.36
"	5.0	3	"	1.82	3.64	5.45	7.27	9.09	10.91
"	7.5	4.5	"	2.73	5.45	8.18	10.91	13.64	16.37
"	10.0	6	"	3.64	7.27	10.91	14.55	18.18	21.82
"	15.0	9	"	5.45	10.91	16.36	21.82	27.27	32.73

*Width of spray as stated above is figured for one man.
1 to 5 feet to be covered by single-man unit.
7.5 to 15 feet to be covered by either single-man or multiple-man unit.

Airplane Spray Tests: Airplane spraying of herbicides for weed control has been developed and conducted on the mainland for the last two years. Several airplane spraying companies have been formed. Several thousands of acres of small grains, corn, rice and alfalfa were sprayed throughout the several states with 2,4-D and the dinitro weed killers in 1947. Upwards of 100,000 acres of spring wheat were sprayed in the Red River Valley and the adjoining states of Minnesota, North and South Dakota last year. Some 1,800 acres of corn were successfully treated for weed control in Nebraska by airplane. All of this spraying

was done for selective weed control in the crops with contact sprays of the above herbicides. For the greater percentage of the spraying, the esters of 2,4-D in either water or Diesel oil were applied at dosages of from ¼ to 1 pound 2,4-D acid per acre in from one quart to ten gallons of diluent per acre. The dinitro compounds in water or Diesel oil were used on alfalfa. No 2,4-D was used on this crop. Most of the alfalfa spraying was done in California. The dinitro compounds were sprayed by plane in as high as 30 gallons per acre of diluent. Most of the planes used were the Boeing-built Stearman-type biplanes.

The airplane method of application of herbicides is under investigation in Hawaii at present. Personnel of several of the irrigated plantations are interested in this method as a possible means of increasing the efficiency of weed spraying by uniform application quickly applied at the proper time, particularly as soil treatments for pre-emergence control. It is hoped also that the cost of application can thus be reduced, and that less chemical will be needed through more efficient application with perhaps fewer applications than where knapsack or pressure-tank gangs are used.

Studies have been made of the possibilities of the use of airplane spraying at two different times on two different plantations where tests were being conducted. Glass plates were laid out across the flight path to check the spray pattern of both 2,4-D ester in oil and 2,4-D acid in water slurry. The spray patterns in both cases looked entirely satisfactory, with a variation in number of droplets per square inch varying from 36 to 144. The percentage of total coverage has varied from 10 to almost 100, where the herbicide has been applied in five gallons of diluent per acre. Even the 10 per cent coverage appeared satisfactory. It is not known definitely what percentage of total cover is needed for maximum control. Results on the mainland have shown that a close, uniform pattern of droplets has given excellent weed control when applied as a selective contact spray to weeds in various crops.

The question has been asked several times whether any part of a herbicidal spray, and especially of 2,4-D, may be volatilized and thereby drift with the wind as a gas rather than in the liquid form. An attempt was made to study this matter in cooperation with J. Don Campbell of the Murray Airplane Dusting Company and H. A. Alexander, Maui Island Representative. Tests were conducted at Maui Agricultural Company on March 26, 1948. On the following pages are shown the technique followed and the results obtained from a limited experiment (see Fig. 12).

The spray pattern, pre-emergence effect on lettuce seed, and contact effect on tomato plants were checked at different distances from the plane when spraying was done both directly against the wind and directly sidewind. The spray pattern was checked on glass slides. Petri plates with wet filter papers were exposed and later had lettuce seed placed in them to check the effect on germination. Tomato plants were exposed to the spray at distances up to 500 feet to determine whether the plants would show any effect of 2,4-D beyond the point of intercepting liquid spray. The isopropyl ester of 2,4-D at the dosage of five pounds in five gallons Diesel oil per acre was the herbicide used. The wind velocity was ten to fourteen miles per hour. The results are shown in the table IV. It is shown that from the sidewind flight liquid spray was intercepted at from 12.5 to 200 feet downwind from the plane. The plant index shows that

curvature due to 2,4-D was noted at 500 feet downwind, 300 feet beyond interception of liquid spray. From the headwind flight, droplets were intercepted from 25 feet on the right to 50 feet on the left. Epinastic curvature was noted on the plant at 100 feet from the plane, but no apparent effect at 500 feet. The effect on the plants was noticed within three hours following treatment, but was indexed at 48 hours. No results are as yet available regarding the pre-emergence effect on lettuce seed.

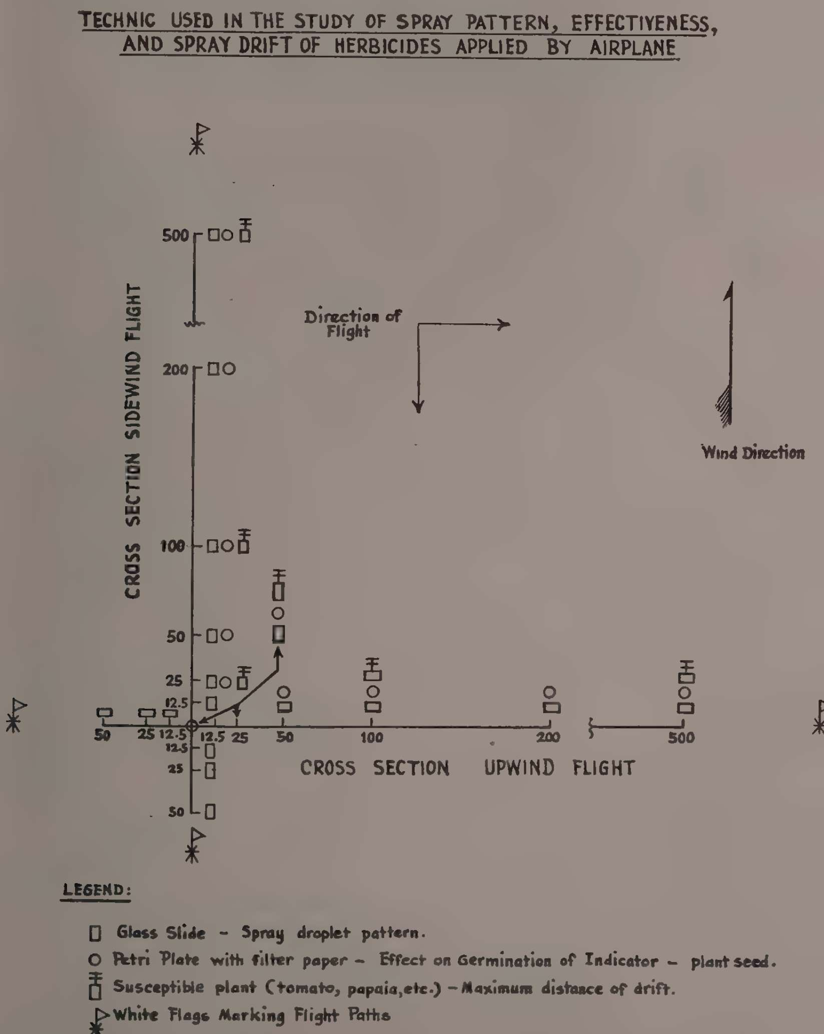


Fig. 12.

The results obtained are from limited experiments and cannot be conclusive. They indicate, however, that under the conditions of this experiment some 2,4-D apparently was carried in a form which could not be intercepted on glass slides and which was probably gaseous.

It must be pointed out that the wind velocity was higher than acceptable for airplane spraying and normally no spraying would be done under such conditions. There are times, however, when gusts may reach this velocity or spraying may have to be finished during winds of this velocity. Mr. Alexander and Mr. Campbell are planning to continue experiments of this type under more favorable conditions.

TABLE IV

AIRPLANE SPRAY TESTS—MAUI AGRICULTURAL COMPANY

March 26, 1948

Test No.	Chemical	Lbs. per acre	Gals. per acre	Wind Vel. mph	Noz. Type	Pressure per sq. in.	Speed in mph	Distance from plane* L or DW	R or UW	Droplets per sq. in† No.	Size	Germination‡ Index	Susceptible Plant¶ Index
						Direct Sidewind Flight							3/28/48
1	Isopropyl	5	5	10	Mod.	65	85	—	50	0	—	Test	—
"	ester in	"	"	"	Whirl-	"	"	—	25	0	—	incom-	—
"	diesel oil	"	"	"	Jet	"	"	—	12.5	0	—	plete	—
"	"	"	"	"	"	"	"	0	0	0	—	"	5
"	"	"	"	"	"	"	"	12.5	—	1	1/8"	"	—
"	"	"	"	"	"	"	"	25	—	34	1/16"	"	5
"	"	"	"	"	"	"	"	50	—	27	1/24"	"	—
"	"	"	"	"	"	"	"	100	—	4	1/24"	"	4
"	"	"	"	"	"	"	"	200	—	3	1/16"	"	—
"	"	"	"	"	"	"	"	500	—	0	—	"	3
						Direct Headwind Flight							
2	Isopropyl	5	5	14	Mod.	65	85	—	50	0	—	Test	—
"	ester in	"	"	"	Whirl-	"	"	—	25	129	1/32"	incom-	—
"	diesel oil	"	"	"	Jet	"	"	—	12.5	84	1/8"	plete	—
"	"	"	"	"	"	"	"	0	0	50	3/32"	"	5
"	"	"	"	"	"	"	"	12.5	—	57	1/16"	"	—
"	"	"	"	"	"	"	"	25	—	54	1/24"	"	5
"	"	"	"	"	"	"	"	50	—	8	1/32"	"	—
"	"	"	"	"	"	"	"	100	—	0	—	"	3
"	"	"	"	"	"	"	"	200	—	0	—	"	—
"	"	"	"	"	"	"	"	500	—	0	—	"	1

*L or DW = Left side on headwind flight or down wind on sidewind flight.
R or UW = Right side on headwind flight or up wind on sidewind flight.
O = Center of flight path.

†Average of three counts per slide.

‡Germination Index:
1 = 0—50% inhibition of germination
2 = 50—70% " " "
3 = 70—85% " " "
4 = 85—95% " " "
5 = 95—100% " " "

¶Susceptible plant index:
1 = No apparent effect.
2 = Slight curvature—color normal.
3 = Intermediate curvature—color normal.
4 = Intense curvature—color abnormal.
5 = Extreme twisting—leaves dead or dying.

Since the development of 2, 4-D as a growth regulating herbicide and the several other chemical weed killers, much effort has been directed toward the development of effective and economical application methods. In general, the equipment that has received attention for application of weed killing chemicals has included both spraying and dusting equipment that is hand operated, power operated ground rigs, and airplane mounted units. Special applicators such as turbines, blowers, and fog machines have also been tried. Thus far equipment for the spraying of low volumes of highly concentrated liquids has proved the most practical.

The basic unit of spray equipment used for treating weeds is as follows:

1. An adequate supply tank.
2. A pump and power unit, the pump being capable of supplying constant pressure in the range from 20 to 40 pounds per square inch. Pressures lower than 30 p. s. i. do not divide the spray finely enough with most nozzles and only with special nozzles should pressures lower than 30 p. s. i. be used. Pressures higher than 40 p. s. i. should be avoided except for tall, dense vegetation. Pressures higher than 40 p. s. i. cause the spray to be so finely divided that much is lost in drifting mist. Where high-pressure pumps are used and these are difficult to adjust to the 30-to 40-pound range, it may be advanatgeous to use a pressure regulator which will maintain a constant pressure. This is also the case where the pump is run off a power takeoff and the initial pressure varies with the speed of the motor. Pumps that have proved satisfactory for spraying have included the plunger, turbine, rotary gear or impeller, rubber impeller, and centrifugal types, especially the multiple-stage centrifugal pumps. The Norgren, Watt, and Masonielan 227 pressure regulators have proved satisfactory. The latter is for pressure tanks.

   Compressor and pressure tank-type sprayers have proved satisfactory and may be desired where abrasive materials are present in the water to be used for spraying. Such abrasive materials do not pass through working parts in a pressure unit as is the case with the pump units mentioned above. Constant pressure is more assured with the pressure units. There is, on the other hand, greater danger involved in the use of the pressure tank than with the pump units. Individually carried pressure tanks charged by protable compressors or high-pressure cartridges can more satisfactorily supply several nozzles on an interline boom than is the case with the knapsack sprayers with hand plunger pumps. The latter are incapable of constant pressure, the pressure varying as much as 10 to 15 pounds per stroke of the pump.
3. A rigidly mounted, folding boom for broadcast or inter-row spraying, with fan-type nozzles spaced at uniform intervals to give accurate, uniform coverage. Setting of the boom high enough for double coverage is desirable where there is little danger of strong wind and

drifting of the spray. (Nozzle sizes are given in the Calibration Tables following.)

4. A hose and spray gun are desirable for spraying areas missed or inaccessible by the boom.

While the above parts are necessary in a basic unit, the calibration of the sprayer is dependent on four factors which can be varied. These are:

1. Nozzle orifice size regulating delivery per minute at a given pressure.
2. Nozzle spacing on the boom or individual nozzle coverage.
3. Pressure.
4. Forward speed over the area being sprayed.

The following formulae are of value in the calibration of spray equipment.

Formula No. 1—For use in determining the speed of travel required to apply a specific number of gallons per acre. (See Calibration Table No. 1.)

$$\text{Miles per hour} = \frac{495 \times \text{Gallons per minute per nozzle}}{\text{Nozzle spacing in feet} \times \text{Gallons per Acre}}$$

Example: The sprayer has nozzles spaced 18 inches or 1½ feet apart on the boom, each delivering .2 gallon per minute with pressure set at 40 pounds per square inch. But it is desired to apply 22 gallons per acre. Then:

$$\text{M.P.H.} = \frac{495 \times .2}{1.5 \times 22} = \frac{99}{33} = 3 \text{ miles per hour}$$

Formula No. 2:—For use in determining the actual number of gallons applied per acre with different adjustments at specific speeds. (See Calibration Table No. 2.)

$$\text{Gallons per Acre} = \frac{495 \times \text{Gallons per minute per nozzle}}{\text{Nozzle spacing in feet} \times \text{Miles per hour}}$$

Example: The sprayer has nozzles spaced 18 inches or 1½ feet apart on the boom, each delivering .2 gallon per minute with pressure set at 40 pounds per square inch as above. The forward speed is 3 miles per hour. Then:

$$\text{G.P.A.} = \frac{495 \times .2}{1.5 \times 3} = \frac{99}{4.5} = 22 \text{ gallons per acre}$$

The following Calibration Tables may be used as a guide but for accurate calibration, each sprayer should be prepared with the desired nozzle size at uniform spacings on the boom, the pressure adjusted to 30 or 40 pounds, the delivery of several nozzles checked, and the calibration calculated for the particular adjustment of that spraying unit.

CALIBRATION TABLE NO. 1
FOR SPECIFIC NUMBER OF GALLONS PER ACRE

(Teejet Nozzles)*

$$\text{Formula: M.P.H.} = \frac{495 \times \text{G.P.M. Per Nozzle}}{\text{Noz. Spacing in feet} \times \text{Gals. per acre}}$$

Rate per acre gals.	Rate per 1/100 ac. c.c.	Nozzle No.	Nozzle Orifice inch	Nozzle delivery G.P.M.	Nozzle Spacing inches	Nozzle Spacing feet	Pres-sure/ sq. in.	Forward speed of sprayer mi./hour	Forward speed of sprayer feet/minute	Forward speed of sprayer Inches/second
2½	94.6	L.N.1.27	.028	.021	12	1.0	20	4.16	366.08	73.22
5	189.2	650067	.021	.06	12	1.0	30	5.94	522.72	104.54
"	"	"	"	"	15	1.25	"	4.75	418.00	83.60
"	"	"	"	.067	12	1.0	40	6.63	583.44	116.69
"	"	"	"	"	15	1.25	"	5.31	467.28	93.46
10	378.4	8001	.020	.09	12	1.0	30	4.46	392.48	78.50
"	"	"	"	"	15	1.25	"	3.56	313.28	62.66
"	"	"	"	"	18	1.5	"	2.97	261.36	52.27
"	"	"	"	.10	12	1.0	40	4.95	435.60	87.12
"	"	"	"	"	15	1.25	"	3.96	348.48	69.70
"	"	"	"	"	18	1.5	"	3.30	290.40	58.08
15	567.6	8001	.020	.09	12	1.0	30	2.97	261.36	52.27
"	"	"	"	"	15	1.25	"	2.38	209.44	41.89
"	"	"	"	"	18	1.5	"	1.98	174.24	34.85
"	"	"	"	.10	12	1.0	40	3.30	290.40	58.08
"	"	"	"	"	15	1.25	"	2.64	232.32	46.46
"	"	"	"	"	18	1.5	"	2.20	193.60	38.72
20	756.8	8002	1/32	.17	12	1.0	30	4.21	370.48	74.10
"	"	"	"	"	15	1.25	"	3.37	296.56	59.31
"	"	"	"	"	18	1.5	"	2.81	247.28	49.46
"	"	"	"	.20	12	1.0	40	4.95	435.60	87.12
"	"	"	"	"	15	1.25	"	3.96	348.48	69.70
"	"	"	"	"	18	1.5	"	3.30	290.40	58.08
25	946.0	8002	1/32	.17	12	1.0	30	3.37	296.56	59.31
"	"	"	"	"	15	1.25	"	2.69	236.72	47.34
"	"	"	"	"	18	1.5	"	2.24	197.12	39.42
"	"	"	"	.20	12	1.0	40	3.96	348.48	69.70
"	"	"	"	"	15	1.25	"	3.17	278.96	55.79
"	"	"	"	"	18	1.5	"	2.64	232.32	46.46
30	1135.2	8002	1/32	.17	12	1.0	30	2.81	247.28	49.46
"	"	"	"	"	15	1.25	"	2.24	197.12	39.42
"	"	"	"	"	18	1.5	"	1.87	164.56	32.91
"	"	"	"	.20	12	1.0	40	3.30	290.40	58.08
"	"	"	"	"	15	1.25	"	2.64	232.32	46.46
"	"	"	"	"	18	1.5	"	2.20	193.60	38.72
"	"	8003	.043	.26	12	1.0	30	4.29	377.52	75.50
"	"	"	"	"	15	1.25	"	3.43	301.84	60.37
"	"	"	"	"	18	1.5	"	2.86	251.68	50.34
"	"	"	"	.30	12	1.0	40	4.95	435.60	87.12
"	"	"	"	"	15	1.25	"	3.96	348.48	69.70
"	"	"	"	"	18	1.5	"	3.30	290.40	58.08

CALIBRATION TABLE No. 1—(Continued)
FOR SPECIFIC NUMBER OF GALLONS PER ACRE

(Teejet Nozzles)*

Rate per acre gallons	Rate per 1/100 ac. c.c.	Nozzle No.	Nozzle Orifice Inch	Nozzle delivery G.P.M.	Nozzle Spacing inch	Nozzle Spacing feet	Pressure/ sq. in.	Forward speed of sprayer mile/ hour	feet/ minute	Inches/ Second
40	1513.6	8004	3/64	.35	12	1.0	30	4.33	381.04	76.21
"	"	"	"	"	15	1.25	"	3.47	305.36	61.07
"	"	"	"	"	18	1.5	"	2.89	254.32	50.86
"	"	"	"	.40	12	1.0	40	4.95	435.60	87.12
"	"	"	"	"	15	1.25	"	3.96	348.48	69.70
"	"	"	"	"	18	1.5	"	3.30	290.40	58.08
50	1892.0	8004	3/64	.35	12	1.0	30	3.47	305.36	61.07
"	"	"	"	"	15	1.25	"	2.77	243.76	48.75
"	"	"	"	"	18	1.5	"	2.31	203.28	40.66
"	"	"	"	.40	12	1.0	40	3.96	348.48	69.70
"	"	"	"	"	15	1.25	"	3.17	278.96	55.79
"	"	"	"	"	18	1.5	"	2.64	232.32	46.46
75	2838.0	8006	1/16	.52	12	1.0	30	3.43	301.84	60.37
"	"	"	"	"	15	1.25	"	2.75	242.00	48.40
"	"	"	"	"	18	1.5	"	2.29	201.52	40.30
"	"	"	"	.60	12	1.0	40	3.96	348.48	69.70
"	"	"	"	"	15	1.25	"	3.17	278.96	55.79
"	"	"	"	"	18	1.5	"	2.64	232.32	46.46
100	3784.0	8010	5/64	.86	12	1.0	30	4.26	374.88	74.98
"	"	"	"	"	15	1.25	"	3.41	300.08	60.02
"	"	"	"	"	18	1.5	"	2.84	249.92	49.98
"	"	"	"	1.0	12	1.0	40	4.95	435.60	87.12
"	"	"	"	"	15	1.25	"	3.96	348.48	69.70
"	"	"	"	"	18	1.5	"	3.30	290.40	58.08

*This table is calculated on the basis of Spraying Systems Teejet Nozzles. The same applies to the Monarch or any other make of nozzle with similar orifice sizes.

CALIBRATION TABLE NO. 2
FOR SPECIFIC NUMBER OF MILES PER HOUR

(Teejet Nozzles)*

$$\text{Formula: G.P.A.} = \frac{495 \times \text{G.P.M. Per Noz.}}{\text{Noz. Spacing in ft.} \times \text{M.P.H.}}$$

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
1	88	17.6	12	1	20	L.N.1.27	.021	10.40
"	"	"	"	"	"	650067	.05	24.75
"	"	"	"	"	"	8001	.07	34.65
"	"	"	"	"	"	8002	.14	69.30
"	"	"	"	"	"	8004	.28	138.60
"	"	"	"	"	"	8006	.42	207.90
"	"	"	"	"	30	L.N.1.27	.025	12.38
"	"	"	"	"	"	650067	.06	29.70
"	"	"	"	"	"	8001	.09	44.55
"	"	"	"	"	"	8002	.17	84.15
"	"	"	"	"	"	8004	.35	173.25
"	"	"	"	"	"	8006	.52	257.40
"	"	"	"	"	40	650067	.067	33.17
"	"	"	"	"	"	8001	.10	49.50
"	"	"	"	"	"	8002	.20	99.00
"	"	"	"	"	"	8004	.40	198.00
"	"	"	"	"	"	8006	.60	297.00
"	"	"	15	1.25	20	650067	.05	19.80
"	"	"	"	"	"	8001	.07	27.72
"	"	"	"	"	"	8002	.14	55.44
"	"	"	"	"	"	8004	.28	110.88
"	"	"	"	"	"	8006	.42	166.32
"	"	"	"	"	30	650067	.06	23.76
"	"	"	"	"	"	8001	.09	35.64
"	"	"	"	"	"	8002	.17	67.32
"	"	"	"	"	"	8004	.35	138.60
"	"	"	"	"	"	8006	.52	205.92
"	"	"	"	"	40	650067	.067	26.53
"	"	"	"	"	"	8001	.10	39.60
"	"	"	"	"	"	8002	.20	79.20
"	"	"	"	"	"	8004	.40	158.40
"	"	"	"	"	"	8006	.60	237.60
"	"	"	18	1.50	20	650067	.05	16.50
"	"	"	"	"	"	8001	.07	23.10
"	"	"	"	"	"	8002	.14	46.20
"	"	"	"	"	"	8004	.28	92.40
"	"	"	"	"	"	8006	.42	138.60

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
1	88	17.6	18	1.50	30	650067	.06	19.80
"	"	"	"	"	"	8001	.09	29.70
"	"	"	"	"	"	8002	.17	56.10
"	"	"	"	"	"	8004	.35	115.50
"	"	"	"	"	"	8006	.52	171.60
"	"	"	"	"	40	650067	.067	22.11
"	"	"	"	"	"	8001	.10	33.00
"	"	"	"	"	"	8002	.20	66.00
"	"	"	"	"	"	8004	.40	132.00
"	"	"	"	"	"	8006	.60	198.00
2	176	35.2	12	1	20	L.N.1.27	.021	5.20
"	"	"	"	"	"	650067	.05	12.38
"	"	"	"	"	"	8001	.07	17.33
"	"	"	"	"	"	8002	.14	34.65
"	"	"	"	"	"	8004	.28	69.30
"	"	"	"	"	"	8006	.42	103.95
"	"	"	"	"	30	L.N.1.27	.025	6.19
"	"	"	"	"	"	650067	.06	14.85
"	"	"	"	"	"	8001	.09	22.28
"	"	"	"	"	"	8002	.17	42.08
"	"	"	"	"	"	8004	.35	86.63
"	"	"	"	"	"	8006	.52	128.70
"	"	"	"	"	40	650067	.067	16.58
"	"	"	"	"	"	8001	.10	24.75
"	"	"	"	"	"	8002	.20	49.50
"	"	"	"	"	"	8004	.40	99.00
"	"	"	"	"	"	8006	.60	148.50
"	"	"	15	1.25	20	650067	.05	9.90
"	"	"	"	"	"	8001	.07	13.86
"	"	"	"	"	"	8002	.14	27.72
"	"	"	"	"	"	8004	.28	55.44
"	"	"	"	"	"	8006	.42	83.16
"	"	"	"	"	30	650067	.06	11.88
"	"	"	"	"	"	8001	.09	17.82
"	"	"	"	"	"	8002	.17	33.66
"	"	"	"	"	"	8004	.35	69.30
"	"	"	"	"	"	8006	.52	102.96
"	"	"	"	"	40	650067	.067	13.27
"	"	"	"	"	"	8001	.10	19.80
"	"	"	"	"	"	8002	.20	39.60
"	"	"	"	"	"	8004	.40	79.20
"	"	"	"	"	"	8006	.60	118.80

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
2	176	35.2	18	1.50	20	650067	.05	8.25
"	"	"	"	"	"	8001	.07	11.55
"	"	"	"	"	"	8002	.14	23.10
"	"	"	"	"	"	8004	.28	46.20
"	"	"	"	"	"	8006	.42	69.30
"	"	"	"	"	30	650067	.06	9.90
"	"	"	"	"	"	8001	.09	14.85
"	"	"	"	"	"	8002	.17	28.05
"	"	"	"	"	"	8004	.35	57.75
"	"	"	"	"	"	8006	.52	85.80
"	"	"	"	"	40	650067	.067	11.06
"	"	"	"	"	"	8001	.10	16.50
"	"	"	"	"	"	8002	.20	33.00
"	"	"	"	"	"	8004	.40	66.00
"	"	"	"	"	"	8006	.60	99.00
2½	220	44.0	12	1	20	L.N.1.27	.021	4.16
"	"	"	"	"	"	650067	.05	9.90
"	"	"	"	"	"	8001	.07	13.86
"	"	"	"	"	"	8002	.14	27.72
"	"	"	"	"	"	8004	.28	55.44
"	"	"	"	"	"	8006	.42	83.16
"	"	"	"	"	30	L.N. 1.27	.025	4.95
"	"	"	"	"	"	650067	.06	11.88
"	"	"	"	"	"	8001	.09	17.82
"	"	"	"	"	"	8002	.17	33.66
"	"	"	"	"	"	8004	.35	69.30
"	"	"	"	"	"	8006	.52	102.96
"	"	"	"	"	40	650067	.067	13.27
"	"	"	"	"	"	8001	.10	19.80
"	"	"	"	"	"	8002	.20	39.60
"	"	"	"	"	"	8004	.40	79.20
"	"	"	"	"	"	8006	.60	118.80
"	"	"	15	1.25	20	650067	.05	7.92
"	"	"	"	"	"	8001	.07	11.09
"	"	"	"	"	"	8002	.14	22.18
"	"	"	"	"	"	8004	.28	44.35
"	"	"	"	"	"	8006	.42	66.53
"	"	"	"	"	30	650067	.06	9.50
"	"	"	"	"	"	8001	.09	14.26
"	"	"	"	"	"	8002	.17	26.93
"	"	"	"	"	"	8004	.35	55.44
"	"	"	"	"	"	8006	.52	82.37

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
2½	220	44.0	15	1.25	40	650067	.067	10.62
"	"	"	"	"	"	8001	.10	15.84
"	"	"	"	"	"	8002	.20	31.68
"	"	"	"	"	"	8004	.40	63.36
"	"	"	"	"	"	8006	.60	95.04
"	"	"	18	1.50	20	650067	.05	6.60
"	"	"	"	"	"	8001	.07	9.24
"	"	"	"	"	"	8002	.14	18.48
"	"	"	"	"	"	8004	.28	36.96
"	"	"	"	"	"	8006	.42	55.44
"	"	"	"	"	30	650067	.06	7.92
"	"	"	"	"	"	8001	.09	11.88
"	"	"	"	"	"	8002	.17	22.44
"	"	"	"	"	"	8004	.35	46.20
"	"	"	"	"	"	8006	.52	68.64
"	"	"	"	"	40	650067	.067	8.84
"	"	"	"	"	"	8001	.10	13.20
"	"	"	"	"	"	8002	.20	26.40
"	"	"	"	"	"	8004	.40	52.80
"	"	"	"	"	"	8006	.60	79.20
3	264	52.8	12	1	20	L.N. 1.27	.021	3.47
"	"	"	"	"	"	650067	.05	8.25
"	"	"	"	"	"	8001	.07	11.55
"	"	"	"	"	"	8002	.14	23.10
"	"	"	"	"	"	8004	.28	46.20
"	"	"	"	"	"	8006	.42	69.30
"	"	"	"	"	30	L.N. 1.27	.025	4.12
"	"	"	"	"	"	650067	.06	9.90
"	"	"	"	"	"	8001	.09	14.83
"	"	"	"	"	"	8002	.17	28.05
"	"	"	"	"	"	8004	.35	57.75
"	"	"	"	"	"	8006	.52	85.80
"	"	"	"	"	40	650067	.067	11.06
"	"	"	"	"	"	8001	.10	16.50
"	"	"	"	"	"	8002	.20	33.00
"	"	"	"	"	"	8004	.40	66.00
"	"	"	"	"	"	8006	.60	99.00
"	"	"	15	1.25	20	650067	.05	6.60
"	"	"	"	"	"	8001	.07	9.24
"	"	"	"	"	"	8002	.14	18.48
"	"	"	"	"	"	8004	.28	36.96
"	"	"	"	"	"	8006	.42	55.44

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal P.A.
3	264	52.8	15	1.25	30	650067	.06	7.92
"	"	"	"	"	"	8001	.09	11.88
"	"	"	"	"	"	8002	.17	22.44
"	"	"	"	"	"	8004	.35	46.20
"	"	"	"	"	"	8006	.52	68.64
"	"	"	"	"	40	650067	.067	8.84
"	"	"	"	"	"	8001	.10	13.20
"	"	"	"	"	"	8002	.20	26.40
"	"	"	"	"	"	8004	.40	52.80
"	"	"	"	"	"	8006	.60	79.20
"	"	"	18	1.50	20	650067	.05	5.50
"	"	"	"	"	"	8001	.07	7.70
"	"	"	"	"	"	8002	.14	15.40
"	"	"	"	"	"	8004	.28	30.80
"	"	"	"	"	"	8006	.42	46.20
"	"	"	"	"	30	650067	.06	6.60
"	"	"	"	"	"	8001	.09	9.90
"	"	"	"	"	"	8002	.17	18.70
"	"	"	"	"	"	8004	.35	38.50
"	"	"	"	"	"	8006	.52	57.20
"	"	"	"	"	40	650067	.067	7.37
"	"	"	"	"	"	8001	.10	11.00
"	"	"	"	"	"	8002	.20	22.00
"	"	"	"	"	"	8004	.40	44.00
"	"	"	"	"	"	8006	.60	66.00
3½	308	61.6	12	1	20	L.N. 1.27	.021	2.97
"	"	"	"	"	"	650067	.05	7.07
"	"	"	"	"	"	8001	.07	9.90
"	"	"	"	"	"	8002	.14	19.80
"	"	"	"	"	"	8004	.28	39.60
"	"	"	"	"	"	8006	.42	59.40
"	"	"	"	"	30	L.N. 1.27	.025	3.54
"	"	"	"	"	"	650067	.06	8.49
"	"	"	"	"	"	8001	.09	12.73
"	"	"	"	"	"	8002	.17	24.04
"	"	"	"	"	"	8004	.35	49.50
"	"	"	"	"	"	8006	.52	73.54
"	"	"	"	"	40	650067	.067	9.48
"	"	"	"	"	"	8001	.10	14.14
"	"	"	"	"	"	8002	.20	28.29
"	"	"	"	"	"	8004	.40	56.57
"	"	"	"	"	"	8006	.60	84.86

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
3½	308	61.6	15	1.25	20	650067	.05	5.66
"	"	"	"	"	"	8001	.07	7.92
"	"	"	"	"	"	8002	.14	15.84
"	"	"	"	"	"	8004	.28	31.68
"	"	"	"	"	"	8006	.42	47.52
"	"	"	"	"	30	650067	.06	6.79
"	"	"	"	"	"	8001	.09	10.18
"	"	"	"	"	"	8002	.17	19.23
"	"	"	"	"	"	8004	.35	39.60
"	"	"	"	"	"	8006	.52	58.83
"	"	"	"	"	40	650067	.067	7.58
"	"	"	"	"	"	8001	.10	11.31
"	"	"	"	"	"	8002	.20	22.63
"	"	"	"	"	"	8004	.40	45.26
"	"	"	"	"	"	8006	.60	67.89
"	"	"	18	1.50	20	650067	.05	4.71
"	"	"	"	"	"	8001	.07	6.60
"	"	"	"	"	"	8002	.14	13.20
"	"	"	"	"	"	8004	.28	26.40
"	"	"	"	"	"	8006	.42	39.60
"	"	"	"	"	30	650067	.06	5.66
"	"	"	"	"	"	8001	.09	8.49
"	"	"	"	"	"	8002	.17	16.03
"	"	"	"	"	"	8004	.35	33.00
"	"	"	"	"	"	8006	.52	49.03
"	"	"	"	"	40	650067	.067	6.32
"	"	"	"	"	"	8001	.10	9.43
"	"	"	"	"	"	8002	.20	18.86
"	"	"	"	"	"	8004	.40	37.71
"	"	"	"	"	"	8006	.60	56.57
4	352	70.4	12	1	20	L.N. 1.27	.021	2.60
"	"	"	"	"	"	650067	.05	6.19
"	"	"	"	"	"	8001	.07	8.66
"	"	"	"	"	"	8002	.14	17.33
"	"	"	"	"	"	8004	.28	34.65
"	"	"	"	"	"	8006	.42	51.98
"	"	"	"	"	30	L.N. 1.27	.025	3.09
"	"	"	"	"	"	650067	.06	7.43
"	"	"	"	"	"	8001	.09	11.14
"	"	"	"	"	"	8002	.17	21.04
"	"	"	"	"	"	8004	.35	43.31
"	"	"	"	"	"	8006	.52	64.35

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
4	352	70.4	12	1	40	650067	.067	8.29
"	"	"	"	"	"	8001	.10	12.38
"	"	"	"	"	"	8002	.20	24.75
"	"	"	"	"	"	8004	.40	49.50
"	"	"	"	"	"	8006	.60	74.25
"	"	"	15	1.25	20	650067	.05	4.95
"	"	"	"	"	"	8001	.07	6.93
"	"	"	"	"	"	8002	.14	13.86
"	"	"	"	"	"	8004	.28	27.72
"	"	"	"	"	"	8006	.42	41.58
"	"	"	"	"	30	650067	.06	5.94
"	"	"	"	"	"	8001	.09	8.91
"	"	"	"	"	"	8002	.17	16.83
"	"	"	"	"	"	8004	.35	34.65
"	"	"	"	"	"	8006	.52	51.48
"	"	"	"	"	40	650067	.067	6.63
"	"	"	"	"	"	8001	.10	9.90
"	"	"	"	"	"	8002	.20	19.80
"	"	"	"	"	"	8004	.40	39.60
"	"	"	"	"	"	8006	.60	59.40
"	"	"	18	1.50	20	650067	.05	4.13
"	"	"	"	"	"	8001	.07	5.78
"	"	"	"	"	"	8002	.14	11.55
"	"	"	"	"	"	8004	.28	23.10
"	"	"	"	"	"	8006	.42	34.65
"	"	"	"	"	30	650067	.06	4.95
"	"	"	"	"	"	8001	.09	7.43
"	"	"	"	"	"	8002	.17	14.03
"	"	"	"	"	"	8004	.35	28.88
"	"	"	"	"	"	8006	.52	42.90
"	"	"	"	"	40	650067	.067	5.53
"	"	"	"	"	"	8001	.10	8.25
"	"	"	"	"	"	8002	.20	16.50
"	"	"	"	"	"	8004	.40	33.00
"	"	"	"	"	"	8006	.60	49.50
4½	396	79.2	12	1	20	L.N. 1.27	.021	2.31
"	"	"	"	"	"	650067	.05	5.50
"	"	"	"	"	"	8001	.07	7.70
"	"	"	"	"	"	8002	.14	15.40
"	"	"	"	"	"	8004	.28	30.80
"	"	"	"	"	"	8006	.42	46.20

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
4½	396	79.2	12	1	30	L.N. 1.27	.025	2.75
"	"	"	"	"	"	650067	.06	6.60
"	"	"	"	"	"	8001	.09	9.90
"	"	"	"	"	"	8002	.17	18.70
"	"	"	"	"	"	8004	.35	38.50
"	"	"	"	"	"	8006	.52	57.20
"	"	"	"	"	40	650067	.067	7.37
"	"	"	"	"	"	8001	.10	11.00
"	"	"	"	"	"	8002	.20	22.00
"	"	"	"	"	"	8004	.40	44.00
"	"	"	"	"	"	8006	.60	66.00
"	"	"	15	1.25	20	650067	.05	4.40
"	"	"	"	"	"	8001	.07	6.16
"	"	"	"	"	"	8002	.14	12.32
"	"	"	"	"	"	8004	.28	24.64
"	"	"	"	"	"	8006	.42	36.96
"	"	"	"	"	30	650067	.06	5.28
"	"	"	"	"	"	8001	.09	7.92
"	"	"	"	"	"	8002	.17	14.96
"	"	"	"	"	"	8004	.35	30.80
"	"	"	"	"	"	8006	.52	45.76
"	"	"	"	"	40	650067	.067	5.90
"	"	"	"	"	"	8001	.10	8.80
"	"	"	"	"	"	8002	.20	17.60
"	"	"	"	"	"	8004	.40	35.20
"	"	"	"	"	"	8006	.60	52.80
"	"	"	18	1.50	20	650067	.05	3.67
"	"	"	"	"	"	8001	.07	5.13
"	"	"	"	"	"	8002	.14	10.27
"	"	"	"	"	"	8004	.28	20.53
"	"	"	"	"	"	8006	.42	30.80
"	"	"	"	"	30	650067	.06	4.40
"	"	"	"	"	"	8001	.09	6.60
"	"	"	"	"	"	8002	.17	12.47
"	"	"	"	"	"	8004	.35	25.67
"	"	"	"	"	"	8006	.52	38.13
"	"	"	"	"	40	650067	.067	4.91
"	"	"	"	"	"	8001	.10	7.33
"	"	"	"	"	"	8002	.20	14.67
"	"	"	"	"	"	8004	.40	29.33
"	"	"	"	"	"	8006	.60	44.00
5	440	88.0	12	1	20	L.N.1.27	.021	2.08
"	"	"	"	"	"	650067	.05	4.95
"	"	"	"	"	"	8001	.07	6.93
"	"	"	"	"	"	8002	.14	13.86
"	"	"	"	"	"	8004	.28	27.72
"	"	"	"	"	"	8006	.42	41.58

CALIBRATION TABLE No. 2—(Continued)

(Teejet Nozzles)*

Miles Per Hr.	Ft. Per Min.	Inches Per Sec.	Noz. Spacing Inches	Noz. Spacing Feet	Pressure Sq. In.	Nozzle No.	G.P.M. Per. Noz.	Gal. P.A.
5	440	88.0	12	1	30	L.N.1.27	.025	2.48
"	"	"	"	"	"	650067	.06	5.94
"	"	"	"	"	"	8001	.09	8.91
"	"	"	"	"	"	8002	.17	16.83
"	"	"	"	"	"	8004	.35	34.65
"	"	"	"	"	"	8006	.52	51.48
"	"	"	"	"	40	650067	.067	6.63
"	"	"	"	"	"	8001	.10	9.90
"	"	"	"	"	"	8002	.20	19.80
"	"	"	"	"	"	8004	.40	39.60
"	"	"	"	"	"	8006	.60	59.40
"	"	"	15	1.25	20	650067	.05	3.96
"	"	"	"	"	"	8001	.07	5.54
"	"	"	"	"	"	8002	.14	11.09
"	"	"	"	"	"	8004	.28	22.18
"	"	"	"	"	"	8006	.42	33.26
"	"	"	"	"	30	650067	.06	4.75
"	"	"	"	"	"	8001	.09	7.13
"	"	"	"	"	"	8002	.17	13.46
"	"	"	"	"	"	8004	.35	27.72
"	"	"	"	"	"	8006	.52	41.18
"	"	"	"	"	40	650067	.067	5.31
"	"	"	"	"	"	8001	.10	7.92
"	"	"	"	"	"	8002	.20	15.84
"	"	"	"	"	"	8004	.40	31.68
"	"	"	"	"	"	8006	.60	47.52
"	"	"	18	1.50	20	650067	.05	3.30
"	"	"	"	"	"	8001	.07	4.62
"	"	"	"	"	"	8002	.14	9.24
"	"	"	"	"	"	8004	.28	18.48
"	"	"	"	"	"	8006	.42	27.72
"	"	"	"	"	30	650067	.06	3.96
"	"	"	"	"	"	8001	.09	5.94
"	"	"	"	"	"	8002	.17	11.22
"	"	"	"	"	"	8004	.35	23.10
"	"	"	"	"	"	8006	.52	34.32
"	"	"	"	"	40	650067	.067	4.42
"	"	"	"	"	"	8001	.10	6.60
"	"	"	"	"	"	8002	.20	13.20
"	"	"	"	"	"	8004	.40	26.40
"	"	"	"	"	"	8006	.60	39.60

*This table is calculated on the basis of the Spraying Systems Teejet Nozzles. The same information applies to the Monarch nozzles or any other make delivering the same number of gallons per minute.

ACKNOWLEDGMENT

For the excellent and unusual opportunity to visit and work in the Territory of Hawaii so kindly arranged for by Dr. H. L. Lyon and R. J. Borden—

For the interesting meetings on the several plantations regarding weed control practices and experiments and the congenial friendship enjoyed during these meetings with plantation personnel and Island Representatives of the Experiment Station—

For the fine cooperation of staff members, their associates and Experiment Station personnel in general received in the conducting of special experiments on weeds and on spray equipment, and *many of whose ideas and suggestions are expressed in this report*—

For the many kindnesses extended by Experiment Station and plantation staff members and their families, and

For the efficient services of Florence McCorriston in endless typing, the writer expresses most sincere appreciation and acknowledgment.

History of the Agriculture Department Experiment Station, H. S. P. A. 1895-1945

By R. J. BORDEN

The thirteenth annual meeting of The Planters' Labor and Supply Company was held in Honolulu on November 5, 1894, and we note the following statement regarding the establishment of an Experiment Station for the purpose of improving the production and processing of sugar cane in the Hawaiian Islands. "The Trustees have been in correspondence with Dr. Stubbs of the Louisiana Sugar Experiment Station with the view of procuring the services of an experienced agricultural chemist who might travel about among the different Plantations giving advice to Managers about fertilization and other matters . . ."

The negotiations with Dr. Stubbs resulted in the employment of Dr. Walter Maxwell who arrived in Honolulu on April 2, 1895 to take up his duties as Director of research for the local sugar industry. An article announcing the arrival of Dr. Maxwell, published in April 1895 was entitled "An Agricultural Chemist" and, after enumerating Dr. Maxwell's qualifications, ended by congratulating the agricultural and planting interests of Hawaii on the arrival of an agricultural chemist.

Fig. 1. Early experimental plots at Makiki Station.

By the time of the next annual meeting of the sugar planters in November 1895, Dr. Maxwell had visited all the sugar-producing Islands and nearly all the plantations, and he presented lengthy reports on soils and fertilization,

and was appointed Chairman of the Committees on Fertilization and Cultivation.

Thus it may be truly said that the Agriculture department has been a part and parcel of the Experiment Station since its inception.

Under the direction of Dr. Maxwell, E. G. Clarke was appointed as Field Assistant in 1897 to supervise the experimental field which had been secured and fenced at the corner of Wilder Avenue and Makiki Street. It was here in 1897 that the first of a long series of field experiments was installed by C. F. Eckart. These initial experiments were concerned with determining the response by irrigated Lahaina and Rose Bamboo canes from separate and combined applications of the three major plant foods, and also with a comparison of three sources of nitrogen in complete fertilizers when used both with and without irrigation. In addition, a comparison of fallowing with green manuring was begun, and 18 cane varieties were grown to provide seed for what was to be the beginning of an extensive variety testing program. During the following year tests with seed spacing were added. In 1899 the first irrigation experiments were started.

By 1902 many new varieties of sugar cane were being grown on the experimental field and, in addition to previously mentioned tests, new ones had been installed to study the effects from salty irrigation water, stripping, and of different ages to harvest.

It was not until 1904 that the position of Agriculturist was established and filled by Mr. Clarke. At the same time T. Lougher was engaged as Field Foreman.

The forerunners of what later became known as the Cooperative plantation field experiments were two "substations" on the Island of Hawaii, one laid down at Waiakea and the other at Papaaloa in 1904; both of these were concerned with fertilization. In 1905 the number of these substations was increased to 13 and included sites on all four sugar-producing Islands; five of these experiments were concerned with fertilizers and eight with varieties. In this year the first deliberate propagation of sugar cane from seed was accomplished after much difficulty in getting germination.

The first step towards the standardization of cooperative field experiments under the control of the Experiment Station was taken in 1907 when the Division of Agriculture and Chemistry issued Circulars Nos. 1 and 2. These circulars dealt with "Regulations of the H.S.P.A. Governing the Establishment and Conducting of Substations" and "Proposed Plans for Fertilizer Experiments".

In 1907 J. H. Wale was added to the team of Clarke and Lougher as Substation Assistant. The attention of this group during the next two years was concentrated on the many tests dealing with stripping, with nitrogen spring dressings, and with seedling testing and seed distribution at Makiki and at the outlying substations.

In 1909 a rather drastic change was made in the organization of the Station. From 1904 to 1909 the Station staff was organized into three Divisions—Agriculture and Chemistry, Pathology, and Entomology—each Division having its own Director. The reorganization provided for one Director and five Departments—Agriculture, Chemistry, Pathology, Entomology, and Sugar Technology—thus, the Agriculture department became a separate entity and has continued as such throughout the years.

D. C. Broderick joined the Agriculture staff in 1909.

Clarke and Lougher resigned in 1910. Mr. Clarke was succeeded by F. C. Evans as Agriculturist the same year.

In 1911 Evans and Wale resigned and H. P. Agee and W. P. Naquin became Agriculturist and Assistant Agriculturist respectively. It was in 1911 that authorization for a substation at Waipio was given; the job of taking over the land and planning the area for experimental work was given to Agee and Naquin.

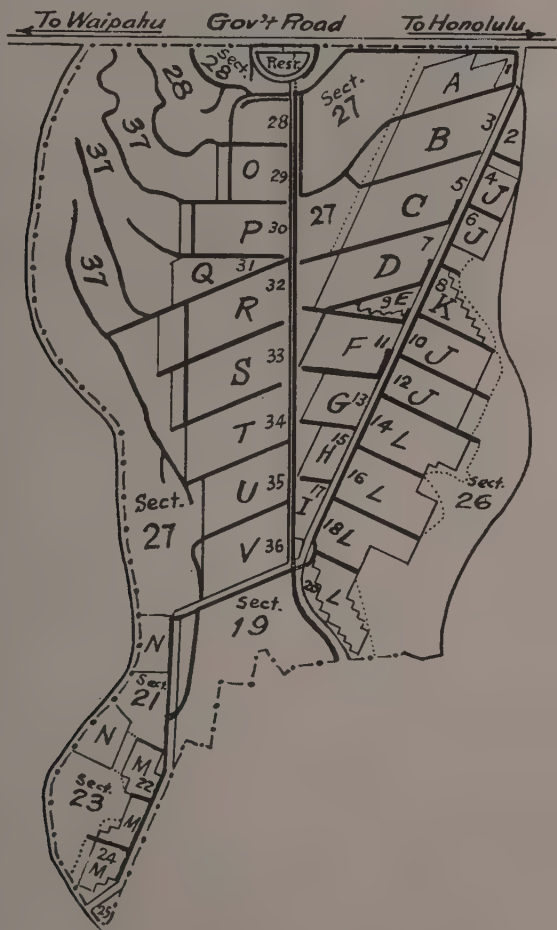


Fig. 2. The original Waipio Substation field plan.

The first 78 acres at Waipahu for the new Waipio substation were laid out and planted in 1912. F. S. Rutledge was the first Superintendent. There were 14 initial experiments, all laid out on a checkerboard plot arrangement. The wide range of problems they sought to answer is indicated in their titles which were as follows:

Expt. A—Irrigation	G—Tankage	M—Fertilizer
B—Fertilizers	H—Experimental error	N—Varieties
C— "	I—Legumes	
D—Time of planting	J—Width of row	
E—Molasses	K—Nitrogen dressing	
F—Hilling up	L—Varieties	

Mr. Naquin was made acting agriculturist in 1913 when Agee became Director of the Experiment Station. Broderick succeeded Rutledge as Superintendent at Waipio and C. W. Kiesel became Foreman at Makiki. Variety testing and the propagation of seedlings, together with the distribution of seed to plantations were the important issues of the day, and tests with green manures were getting much attention.

Fig. 3. Camp buildings and office at Waipio Substation—1914.

Another 56 acres were added to the Waipio substation in 1914 and seven additional tests were installed. These had to do with the following problems:

Expt. O—Liming	R—Fertilizers	U—Companion cropping
P—Irrigation	S— "	
Q—Arsenic	T—Maturing cane	

Naquin was made Agriculturist and L. D. Larsen was transferred from the Pathology department and made his Associate, especially to handle the cooperative plantation experiments. H. C. Brewer was appointed Superintendent at Waipio.

During 1915 and 1916, because there was such a large increase in the number of plantation experiments, the department's staff was increased to handle the newly organized extension work and plantation experiments.

In 1915 we find the Agriculture department organized as follows: Naquin, Agriculturist; Larsen, Associate Agriculturist, and C. D. Rea, who became Superintendent at Waipio when Brewer was sent to Honokaa on special assignment. Problems getting major attention at Waipio were concerned with heavy

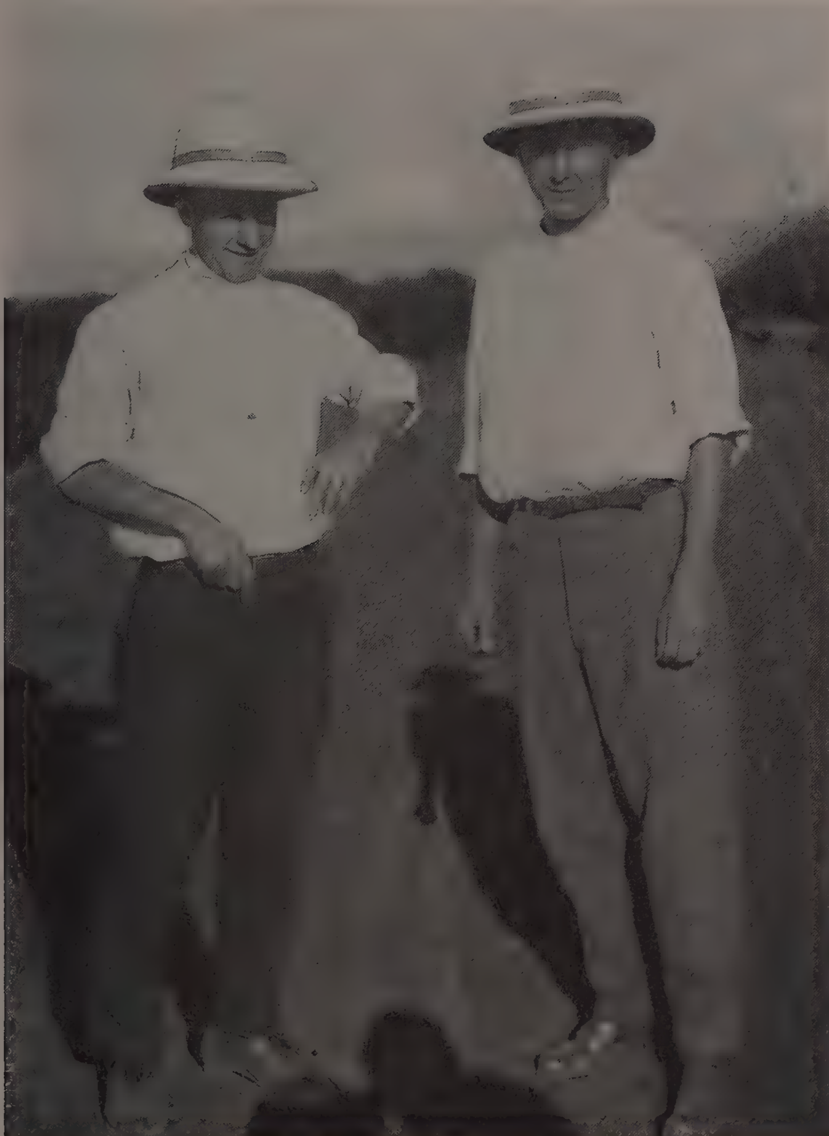


Fig. 4. Left: L. D. Larsen. Right: W. P. Naquin. Associate Agriculturist and Agriculturist—1915.

fertilization, trash conservation, green manuring, second-season nitrogen applications, and 12-month cropping. In addition five new Assistant Agriculturists had been appointed and given special assignments as follows: R. S. Thurston, extension work on Kauai and Maui; J. S. B. Pratt, Jr., extension work on Oahu; R. M. Allen, irrigation investigations; Y. Kutsunai, Field Foreman at Makiki; and R. E. Doty, assistant in pineapple investigations. In February Naquin resigned to become manager of Honokaa.

Fig. 5. Main office of the Agriculture Department—1917. (Messrs. Kutsunai, Allen, Verret and Pratt.)

In 1916 Larsen was appointed Agriculturist, Brewer resigned, and J. A. Verret came from Honolulu Plantation to be Associate Agriculturist. Three additional appointments as Assistant Agriculturists were given to: W. P. Alexander, extension work on Hawaii; J. T. Moir, Jr., general work on Oahu; and L. T. Lyman, Superintendent at Waipio.

Thus in the period 1915-1916 we find the Agriculture department with a very active personnel. This period might well be called the beginning of what later grew to be the training of young men for plantation positions, for actually four of these young assistants eventually became plantation managers.

Fig. 6. Seedling propagation—1917.

Fig. 7. J. A. Verret, Agriculturist—1917.

To provide more land to grow seedling canes for distribution to the plantations, an additional area was purchased (1916) to extend the fields at Makiki. The seedling selection work was greatly expanded. At Waipio special irrigation studies were given prominence.

The Agricultural department had the assistance of Dr. H. L. Lyon and E. L. Caum in its cane improvement studies in 1917. Seedling propagation on all Islands was greatly increased. Over 18,000 seedlings were set out, more than four times as many as in any previous year. Messrs. Alexander, Pratt, Doty, and Lyman entered the armed forces. Mr. Larsen went to Kilauea Plantation as manager and was succeeded by Mr. Verret. Mr. Thurston was made Associate Agriculturist. During 1917 the staff was increased by the following Assistant Agriculturists: M. L. Hartman and P. L. Hesketh.

G. B. Grant joined the staff in 1918 as Assistant Agriculturist, and even with the reduced personnel, Thurston, Allen, Moir, Kutsunai, and Grant managed

to keep over 100 cooperative field tests active on the plantations and to propagate over 10,000 new seedlings. J. T. Moir resigned in November of this year to take a position with the Hawaiian Commercial and Sugar Company.

In 1919 L. T. Lyman rejoined the department and new appointments as Assistant Agriculturists were given to W. L. S. Williams, W. W. G. Moir, R. Pahau, and A. R. Stribling. Alexander returned to the Station but as Assistant to the Director.

Fig. 8. Bud selection activities—H. P. Agee.
Arrangement of holes in Waipio Substation progeny fields.

Later in the year Lyman accepted a position with Pioneer Mill Company, Ltd., and Stribling went to the Koloa Sugar Company. A new substation was established at Manoa for seedling propagation. The more important problems getting attention were concerned with (1) the most profitable limits of nitrogen fertilization, (2) forms of nitrogen, (3) number of applications, (4) filter-press cake values, (5) liming, and (6) methods of cultivation.

The visit of Dr. A. D. Shamel and the start of bud-selection work was the highlight of 1920. Messrs. Verret, Kutsunai, Moir, and Williams participated in the initial selection work. Over 40,000 seedlings were propagated and 139 field experiments were active. Attention was devoted to studies of losses due to delayed milling of burned cane, and much time went into the appraisal of the 1920 strike losses. Worthy of note is the cooperative arrangement entered into with the University of Hawaii whereby advanced students in the sugar technology course became affiliated with the Agricultural department as Student Assistants

for a period of 16 weeks. Mr. Allen resigned to take a position at Kilauea, and new appointments as Assistant Agriculturists went to J. H. Midkiff and H. L. Denison.

In 1921 F. A. Paris and H. K. Stender were appointed Assistant Agriculturists. Bud-selection work by Verret, Kutsunai, Moir, Paris, Grant and Stender held a dominant place during the year. Seedling selections at Makiki by Kutsunai, and on the plantations by Moir, Midkiff, Williams, Denison and Stender were made on canes propagated in previous years. Only a few new propagations were made. Williams resigned to go to Waiakea and was replaced by Mr. Denison; Stender took Denison's place in Kohala; Pahau resigned; and Paris took charge at Waipio.

During 1922 the progeny-selection work was extremely widespread and Verret and his assistants had the cooperation of Mr. Caum of the Botany and Forestry department and of the following plantation men: W. P. Alexander, John Robertson, C. S. Jamison, J. C. Thompson, G. B. Grant, D. H. Hitchcock, E. E. Naquin, D. Seaton, S. Milne, H. E. Starrat, C. F. Poole, J. N. P. Webster, and F. E. Abel. Also during 1922 Thurston retired, and Midkiff, Grant, and W. W. G. Moir resigned to go to Koloa, the Hawaiian Commercial and Sugar Company, and Pioneer Mill Co., Ltd., respectively. H. L. Denison was transferred to the Pineapple department, and W. C. Jennings, J. N. P. Webster and O. C. Markwell were appointed as Assistant Agriculturists. Mr. Pratt rejoined the department as an Associate Agriculturist to devote his time to the extension work.

New appointments as Assistant Agriculturists were given to F. W. Broadbent and R. Conant in 1923. There was a tremendous increase in cane-breeding work with a total of more than 80,000 propagations; a large proportion of these were made by Jennings in Kohala. The first successful Uba crosses were obtained. Wm. Twigg-Smith was called upon to establish the Jeswiet system of identification of cane varieties. Bud-selection work and progeny plantings continued but at a greatly reduced pace. Four Java canes were imported: POJ 36, 213, 234, and 979. Mr. Pratt resigned to accept a position with McBryde Sugar Co., Ltd.

Because the first Uba-D 1135 hybrids appeared so promising, additional Uba hybrids were propagated in 1924. This year also found short cropping getting lots of attention, and much interest in cane-growth measurements. Webster resigned and newly appointed Assistant Agriculturists were A. R. Forbes, F. C. Denison, T. K. Beveridge, J. A. H. Wilder, A. J. Watt, Jr., K. D. Bond, and J. Alunan.

Resignations of Broadbent, Jennings, Bond, Markwell, Paris, and Alunan occurred in 1925, the first three of these men accepting plantation positions. Additional appointments as Assistant Agriculturists were given to D. A. Cooke, D. M. L. Forbes, D. McH. Forbes and D. F. Palmer; R. Bryan and W. H. Deverill were appointed Assistant-Agriculturists-in-Training—the first of a large number of men who later received a similar appointment in the department. The emphasis was still being placed on seedling work and the first successful Caledonia seedlings were obtained. New cane varieties imported through Washington included Kassoer, Kavengire, B.H. 10-12, D.I. 52 and S.W. 3, and the following POJ canes: 228, 826, 2379, 2364, 2714, 2725, 2727 and 36 M.

F. C. Denison was appointed superintendent at Waipio February 1, 1925. The Hawaii plantations were served by A. R. Forbes and Watt. Conant and later McLennan handled the Kauai experiments, and the Maui work was under D. M. L. Forbes.

Assistant Agriculturists appointed in 1926 were S. Takakawa, C. G. Lennox, R. H. McLennan, A. K. Silva, and K. Iwasaki. Mr. Doty rejoined the station as an Assistant Agriculturist and Dr. A. J. Mangelsdorf was appointed as Geneticist. Twigg-Smith cooperated in the cane-breeding work. The emphasis was still on seedling work especially the development of seedlings that would be resistant to eye-spot disease. Altogether a total of over 87,000 seedlings was propagated. Irrigation studies were also prominent with overhead irrigation getting a trial at Waipio and cooperative field studies at Waimanalo plantation being handled by T. K. Beveridge.

Fig. 9. Laying experimental concrete ditch lining at Waipio Substation—1930.

The year 1927 saw great improvements in the technique of maturing cane tassels in sulphurous acid solutions, and to Verret, U. K. Das, and Twigg-Smith goes credit for these improvements. The Kailua substation was started for growing breeding canes and preliminary testing of seedlings. Mathematical studies by Kutsunai demonstrated their applicability and usefulness to many agricultural problems. Lennox was made Assistant Geneticist. O. H. Lyman was appointed an Assistant Agriculturist and the next group of Assistant-Agriculturists-in-Training included Das, V. Eremeef, H. R. Shaw, A. H. Cornelison, G. W. Fisher, E. D. Roberts, H. J. W. Taylor, and J. P. Langley. Resignations were received from R. Conant, A. J. Watt, Jr., V. Eremeef, D. Palmer, and D. M. L. Forbes, the first two accepting plantation positions.

Fig. 10. Tank studies of soil-moisture relationships at Waipio Substation—1931.

There was pressing need for additional area for the testing of seedlings in 1928; over 75,000 new canes were propagated. The hand refractometer became an important tool in the selection work. Cane-ripening and cane-growth tests were getting attention; iron sulphate was proved an effective corrective for chlorosis. Bryan and Cornelison were made Assistant Agriculturists, and appointments as Assistants-in-Training were given to A. Doi, and C. W. Atkinson. Mr. Fisher resigned to accept a position with Kahuku Plantation Company.

Professor H. A. Wadsworth was appointed as Irrigation Specialist in 1929. Webster rejoined the department as Assistant Agriculturist and Das and Shaw were also made Assistant Agriculturists. Langley and M. J. Black were made Junior Assistant Agriculturists, and H. A. Bartels, R. J. Fiddes, R. Urata, and H. L. Weber became Assistants-in-Training. Seedling propagation and testing occupied the leading place in the department's activities. The first Molokai quarantine unit was established. Taylor and Black resigned to accept plantation positions.

Irrigation studies and seedling testing were the leading lines of work in 1930. The tank studies at Waipio were started by Professor Wadsworth and Shaw. The cane-seed tassels from the crosses made in India by Das and in Australia by Lennox were planted at Molokai. Regional stations at Hilo and at Lihue were selected to supplement those at Waipio, Manoa and Kailua. Interest in an improved technique for the field experiments and in the application of statistical methods to the results had been stimulated by the visit of Dr. H. H. Love. Bartels and Fiddes were made Junior Assistant Agriculturists and J. J. Jorgensen, A. Y. Ching, Y. Matsusaka, G. G. Richardson, G. S. Center, N. A. Miller, W. H. Sudduth, and W. McK. Whitman were appointed Assistants-in-Training. Cooke rejoined the department and under his supervision the Mitscherlich soil testing was started. In October, Richardson resigned to accept a plantation position.

The growth in the importance of the cooperative field experiments is seen by the fact that 246 were harvested during 1931 by Verret and his assistants. Climate and cane-growth studies by Das proved some interesting climatic influences. Studies of soil-moisture constants and wilting coefficients of typical sugar-cane soils by Wadsworth and Shaw received much attention. More breeding canes were introduced from Canal Point, Barbados, India and Java, and new importations of fuzz were received from India and Java. Langley accepted a plantation position and the new Assistants-in-Training were E. F. Cushnie, D. T. Silver, A. G. Hansen, D. Forbes, R. P. Northwood, D. B. Thomson, T. G. Eckart, and S. W. Good, Jr. J. P. Langley and Y. Matsusaka resigned to accept plantation positions.

The year 1932 saw the introduction of a new weather measurement—the day-degree; Das' studies had indicated that this could be quite useful. Irrigation studies and Mitscherlich soil testing were the chief lines of work supplementing the extensive testing of varieties and fertilizers. Mr. Verret was honored with the position of Consulting Agriculturist. R. J. Borden joined the department as Associate Agriculturist. Whitman, Shaw, Weber, Thomson, and Cushnie resigned and took up various plantation positions. D. E. Larsen, A. D. Waterhouse, J. A. Swezey, L. W. Crosby, and R. C. Eckart were appointed Assistants-in-Training.

The Hamakua soils study was given major attention by Kutsunai and others

Fig. 11. First installation of six-inch Parshall flume at Waipio Substation—1930.

Fig. 12. Mitscherlich pot, soil-fertility testing—1934.

in 1933. Das continued his contributions from weather and cropping studies. The crossing work was confined almost entirely to the robustum hybrids, the spontaneum and Indian quarter-breeds, and the Australian importations. An effort to get the plantations to take over the routine work, such as that concerned with planting, fertilizing, and harvesting of the field experiments, was made by placing a charge on such service when performed by Station men. A series of Training Bulletins and Agricultural Abstracts were started especially for the 12 Assistants-in-Training. S. M. Miller, W. S. Barnes, K. N. Hanks, J. N. Schenck, and D. S. Judd joined the department as Assistants-in-Training. Hansen, Webster, Crosby, Silver, Hanks, Bryan, Larsen and Schenck took plantation positions in 1933.

The year 1934 saw the separation of all work concerned with cane varieties from the Agricultural department and its transfer to the newly organized Genetics department under the leadership of Dr. Mangelsdorf. Lennox and Stender together with Doi and Urata were transferred to the new department. Borden became Agriculturist with Doty and Kutsunai as his Associates. Bryan, who resigned as Island Representative on Hawaii in 1933 to take a position at Onomea Sugar Company, was succeeded by Miller. Webster who had been Island Representative on Kauai resigned (1933) to go to Kilauea, and T. G. Eckart who followed Webster soon took a position with Lihue (1934); C. C. Barnum who had formerly been with the Pathology department was reemployed as the Kauai Island Representative of the Agriculture and Genetics departments. D. Forbes accepted a position with Hamakua Mill Company. New Assistants-in-Training were F. A. Lyman, A. K. Lyman, G. H. Douse, R. L. Walker and J. W. Anderson. The department lost its senior active member, Mr. Kutsunai, by death. A new plan of work was established for the Agriculture department which included seven major projects. Minimum standards for Grade A experiments were proposed and established to improve the quality of the experimental work. The Mitscherlich tests and the Chemistry department's newly developed rapid soil tests (R.C.M.) now made differential fertilization a real possibility. Wadsworth, with Shaw and Swezey, started intensive studies of soil-moisture relationships.

Irrigation investigations held a prominent place in the work of the department in 1935. The usual large number of cooperative field tests was in existence but since 1933 active participation in the field work of these has been considerably reduced. Miller accepted a position at Kaiwiki Sugar Company and was succeeded as Island Representative on Hawaii by transfer of O. H. Lyman from Maui. Judd succeeded Lyman on Maui. Waterhouse, Anderson, Walker and Barnes took plantation positions. Barnum resigned as Island Representative on Kauai. New Assistants-in-Training were K. H. Berg, W. P. Hodgins, R. A. Cushnie, A. N. Walsh, H. Frazier, and W. J. Baldwin.

L. R. Smith joined the department as an Associate Agriculturist in 1936, and Berg became Assistant Agriculturist. Anderson returned to the department and succeeded Barnum as Island Representative on Kauai. A. K. Lyman, F. A. Lyman, Cushnie and Douse accepted plantation positions. D. M. Hendricks, J. D. Thain, C. E. S. Burns, Jr., H. H. Hall, W. C. Northrup, E. A. Johnstone, and F. F. Hebert were appointed Assistants-in-Training. Special studies were made of supplementary yield data from the Grade A experiments especially to identify the relationships between yields and soil analyses. Skirmish

Fig. 13. R. J. Borden, Agriculturist—1934.

tests covering many problems of soil-plant relationships began to assume an important place in the department's research. A complete revision of the department's Routine Book and the issuance of a set of Purity-Quality Ratio tables were important contributions made in 1936. Another major project—"Studies in Rat Control"—was added to the department activities and assigned specifically to Mr. Doty.

During 1937 the prebait system of rat control was a major contribution. Contact was maintained with more than 200 field experiments chiefly concerned

Fig. 14. Prebaiting for rat control.

with the major plant-food requirements. An "Index Moisture Program" resulted from the cooperative irrigation studies that were conducted on Waialua Plantation. Anderson resigned as Island Representative on Kauai to accept a position with Waialua Agricultural Company, Ltd. Seven of the Assistants-in-Training, Baldwin, Walsh, Burns, Thain, Johnstone and Hall, accepted plantation positions. The following nine new men were appointed Assistants-in-Training: R. D. Wheeler, J. Milne, E. C. Spillner, L. A. Thevenin, J. R.

Garcia, A. L. Faye, R. A. Cooke, Jr., P. Fagan, Jr., and J. K. Williams. Ching was made Assistant in Cane-Growth Studies.

A total of 471 active field experiments in 1938 was largely the effect of the A.A.A. requirements. The principal objective in these tests was still the determination of optimum amounts of specific plant foods. The studies in irrigation practice at Waialua were continued by Wadsworth and Swezey. The training program was greatly strengthened by a reduction in routine activities. Berg resigned as Assistant Agriculturist to accept a position at Lihue, and five of the Trainees—Hendricks, Northrup, Fagan, Hebert, Milne, and Thevenin—also took plantation positions. New Assistants-in-Training were A. C. Stearns, R. E. Jobes, J. A. Verret, Jr., C. R. Weight, R. L. Wold, R. A. Duncan, J. M. Crawford, C. A. Wismer and R. I. Knox.

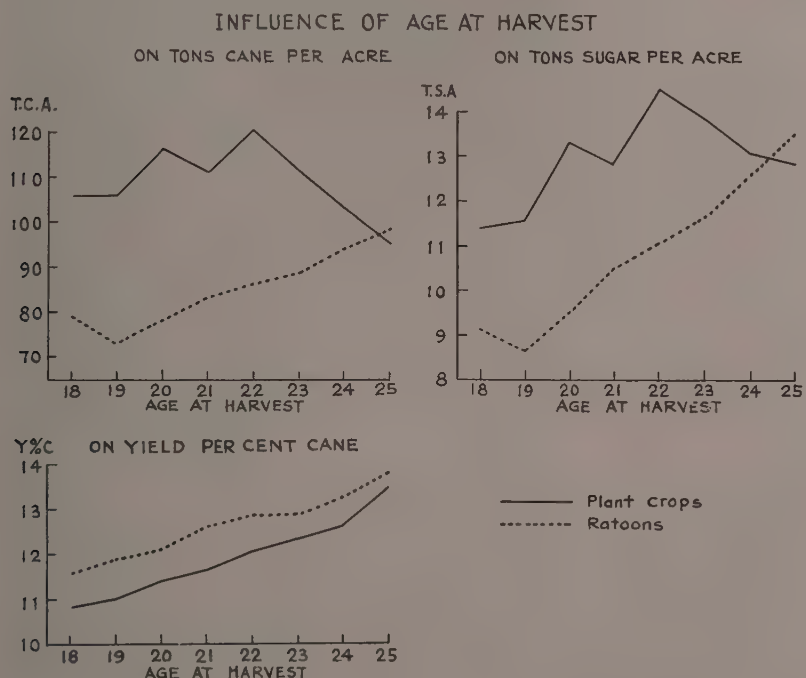


Fig. 15. Yields from H 109 cane at different ages at harvest.

The A.A.A. emphasis upon field experiments continued through 1939 and much activity of the department was concerned with the 447 tests which were started. The factorial plan for field tests was introduced. A major study at Waipio was a very extensive "Age-of-Harvest" test. The training program under Smith and the Island Representatives was in its most active stage. Seven of the Assistants-in-Training—Wheeler, Spillner, Stearns, A. L. Faye, Garcia Jobes, and R. A. Cooke, Jr.—took over plantation or agency positions and the following Trainees were added: J. T. Moir, III, E. M. Faye, W. P. Naquin, Jr., and J. Z. Kissen.

Concern was felt in 1940 over the increase in the experimental error that mechanical harvesting had introduced in field testing. The day-degree plan for irrigation interval control was offered after its trial at Waipio, and Swezey's studies in connection with rainfall evaluation marked an important step forward in irrigation control. A large number of skirmish tests were active; these had to do with such diverse problems as forms of nitrogen, effects of climate, uptake of potash, delayed weeding, delayed fertilization, nitrogen-potash-sunlight relationships, minor element deficiencies, acid or basic residue fertilizers, effects of soil on cane quality, stalk variation, soil puddling, and timing and leaching of nitrogen fertilizers. Eight of the Assistants-in-Training accepted plantation jobs—Verret, Weight, E. M. Faye, Wold, Crawford, Duncan, Wismer and Knox—and new appointments went to D. H. Butchart, K. W. McKenzie, G. B. Stewart, and J. A. Johnson. In addition nine plantation men spent from two to six months each at the Station in a special training program offered for plantation employees.

The field experiment program was greatly reduced in 1941 and only 193 Grade A tests were harvested. The 25-year old Experiment V at Waipio still gave no evidence of phosphate or potash deficiencies. Nitrogen tests in general continued to show but few proved responses to amounts above 150 pounds per acre. Experiments in weed control were getting more attention. Moir and Naquin left to take up plantation positions. R. H. Ward, J. N. Warner and B. McCall were appointed Assistants-in-Training.

Further reduction in the cooperative field testing program took place in 1942 and only 105 tests were harvested. All field activities were greatly reduced. Extensive nitrogen studies received our major attention. Zinc phosphide was proved a very efficient rat poison and fully able to take the place of thallium sulphate which had become a scarce article. McCall accepted a position at Kaeleku, and the training program then became inactive as all of our young trainees (Stewart, Johnson, Ward, Warner) had joined the armed services and no new appointments were made.

The number of field experiments harvested during 1943 was only 80 and concern was expressed that they were being under-valuated. Our chief attention was given to the detailed nitrogen studies on canes being grown at Waipio and at Makiki. Swezey resigned to become head luna at Waianae Plantation. One Assistant-in-Training, R. R. Hind, Jr., was with us for a short time only. Y. Yamasaki was promoted to field assistant. All activity was handicapped by the shortage of labor; the war had forced our field research to its lowest point in many years.

The years 1944 and 1945 brought still further reductions in the number of cooperative plantation field tests. The department's staff was at its lowest point numerically since 1916; Smith after a leave of absence to the War Manpower Commission, resigned in June 1945, and no new replacements of Assistants were made. One Trainee, H. A. Alexander, was appointed in July 1945. Our intensive cooperative nitrogen studies and many of our controlled skirmish tests were continued but it was impossible to undertake investigations of many new problems which needed to be studied; these await attention as we get started on our second fifty years.

The history of the Agriculture department is aptly recorded in papers which

have been prepared by its personnel and subsequently published in *The Hawaiian Planters' Record* for the benefit of all members of our Association.

Three hundred and forty-one articles, reports, and summaries have been prepared by members of the Agriculture department's staff and published in the *Record*. The titles of these papers make an interesting record of the wide range of problems and investigations that have been undertaken and reported upon.

AGRICULTURISTS AND ASSISTANTS WHO HAVE SERVED IN THE AGRICULTURE DEPARTMENT AT THE EXPERIMENT STATION

Appointed		Name	Services Terminated	Status of Those Who Remained with the Hawaiian Sugar Industry
April	1895	WALTER MAXWELL	1904	
Dec.	1895	C. F. ECKART	1904	
	1897	E. G. CLARKE	1910	
Aug.	1904	T. LOUGHER	1910	
	1907	J. H. WALE	1911	
Jan.	1909	D. C. BRODERICK	1914	
	1910	F. EVANS	1911	
June	1911	H. P. AGEE	1913	(Director 1913. Consulting Agriculturist—Castle & Cooke, Ltd. 1936. Deceased December 22, 1942.)
June	1911	W. P. NAQUIN	1915	(Manager Honokaa Sugar Company—Retired 1944.)
Jan.	1912	F. S. RUTLEDGE	1913	
Mar.	1913	C. W. KIESEL	1915	
Oct.	1914	H. C. BREWER	1916	
Dec.	1914	L. D. LARSEN	1917	(Vice-President, C. Brewer & Co., Ltd.—Deceased April 8, 1944.)
June	1915	Y. KUTSUNAI	1934	(Associate Agriculturist, Experiment Station, H.S.P.A.—DeceasedDecember 27, 1934.)
July	1915	C. D. REA	1916	
Sept.	1915	J. S. B. PRATT, JR.	1923	Manager, Kohala Sugar Company.
Nov.	1915	R. M. ALLEN	1920	Manager, Wailuku Sugar Company.
Dec.	1915	R. E. DOTY		Associate Agriculturist, Experiment Station, H.S.P.A.
Dec.	1915	R. S. THURSTON	1922	
Mar.	1916	W. P. ALEXANDER	1921	Manager, Grove Farm Company, Ltd.
June	1916	J. A. VERRET		Consulting Agriculturist, Experiment Station, H.S.P.A.
June	1916	L. T. LYMAN	1919	
Aug.	1916	J. T. MOIR, JR.	1918	Manager, Pioneer Mill Company, Ltd.
Aug.	1917	M. L. HARTMAN	1920	
Dec.	1917	P. L. HESKETH	1918	
May	1918	G. B. GRANT	1922	
Jan.	1919	R. PAHAU	1921	
Feb.	1919	H. R. STRIBLING	1919	
Feb.	1919	W. L. S. WILLIAMS	1921	Manager, Olaa Sugar Company, Ltd.
Sept.	1919	W. W. G. MOIR	1922	Manager, American Factors, Ltd. Plantation Department.
Jan.	1920	J. H. MIDKIFF	1922	Manager, Waialua Agricultural Company, Ltd.
June	1920	H. L. DENISON	1922	
Jan.	1921	F. A. PARIS	1925	

AGRICULTURISTS AND ASSISTANTS WHO HAVE SERVED IN THE AGRICULTURE DEPARTMENT AT THE EXPERIMENT STATION—Continued.

Appointed		Name	Services Terminated	Status of Those Who Remained with the Hawaiian Sugar Industry
June	1921	H. K. Stender		Island Representative (Kauai), Experiment Station, H.S.P.A.
April	1922	W. C. Jennings	1925	Manager, Hakalau Plantation Company.
Aug.	1922	O. C. Markwell	1925	
Nov.	1922	J. N. P. Webster	1933	Head Overseer, Kilauea Sugar Plantation Company.
Mar.	1923	F. W. Broadbent	1925	Agriculturist, Hawaiian Commercial & Sugar Company, Ltd.
July	1923	R. Conant	1927	Cultivation Overseer, Olaa Sugar Company, Ltd.
Mar.	1924	F. C. Denison		Island Representative (Oahu), Experiment Station, H.S.P.A.
June	1924	T. K. Beveridge	1924	Manager, Waimanalo Sugar Company.
July	1924	A. R. Forbes	1928	
Aug.	1924	J. Alunan	1925	
Aug.	1924	J. A. H. Wilder	1926	
Oct.	1924	K. D. Bond	1925	Agriculturist, Kohala Sugar Company.
Dec.	1924	A. J. Watt, Jr.	1927	Division Overseer, Olaa Sugar Company, Ltd.
June	1925	D. McH. Forbes	1925	
June	1925	D. A. Cooke	1936	Research Associate, Experiment Station, H.S.P.A.
July	1925	D. F. Palmer	1927	
Aug.	1925	W. H. Deverill	1928	
Sept.	1925	D. M. L. Forbes	1927	
Nov.	1925	R. Bryan	1933	Manager, Onomea Sugar Company.
Jan.	1926	K. Iwasaki	1926	
April	1926	A. K. Silva	1926	Assistant Director, Industrial Relations, Wailuku Sugar Company.*
June	1926	R. H. McLennan	1932	
Aug.	1926	A. J. Mangelsdorf	1934	Geneticist, Experiment Station, H.S.P.A.
Sept.	1926	C. G. Lennox	1934	
Nov.	1926	S. Takakawa	1934	
June	1927	U. K. Das	1933	(Research Associate, Experiment Station, H.S.P.A.—Deceased October 22, 1937.)
June	1927	V. Eremeef	1927	
July	1927	H. R. Shaw	1932	Irrigation Superintendent, Waialua Agricultural Company, Ltd.*
July	1927	A. H. Cornelison	1932	Research Assistant, Experiment Station, H.S.P.A.
Aug.	1927	G. W. Fisher	1928	Plantation Director.
Aug.	1927	E. D. Roberts	1928	
Aug.	1927	O. H. Lyman		Island Representative (Hawaii), Experiment Station, H.S.P.A.
Oct.	1927	H. J. W. Taylor	1929	Acting Field Superintendent, Ewa Plantation Company.
Oct.	1927	J. P. Langley	1931	Division Overseer, The Lihue Plantation Company, Ltd.
June	1928	A. Doi	1934	Field Assistant, Genetics Department, Experiment Station, H.S.P.A.
Aug.	1928	C. W. Atkinson	1930	

AGRICULTURISTS AND ASSISTANTS WHO HAVE SERVED IN THE AGRICULTURE DEPARTMENT AT THE EXPERIMENT STATION—Continued.

Appointed		Name	Services Terminated	Status of Those Who Remained with the Hawaiian Sugar Industry
Jan.	1929	H. A. Wadsworth	1943	Collaborator in Irrigation, Experiment Station, H.S.P.A.
May	1929	R. J. Fiddes	1932	
May	1929	M. J. Black	1929	Manager, Kilauea Sugar Plantation Company.
May	1929	H. L. Weber	1932	Section Overseer, Hakalau Plantation Company.
May	1929	H. A. Bartels	1932	
June	1929	R. Urata	1934	Field Assistant, Genetics Department. Experiment Station, H.S.P.A.
Jan.	1930	G. G. Richardson	1930	Section Overseer, Waiakea Mill Company.*
Jan.	1930	G. S. Center	1930	
June	1930	Y. Matsusaka	1931	Harvesting Overseer, Honolulu Plantation Company.
June	1930	A. Y. Ching		Field Assistant, Agriculture Department, Experiment Station, H.S.P.A.
June	1930	W. McK. Whitman	1932	Assistant Manager, Hilo Sugar Company.
June	1930	J. J. Jorgensen	1931	
Oct.	1930	W. H. Sudduth	1932	
Nov.	1930	N. A. Miller	1931	
Feb.	1931	E. F. Cushnie	1932	
June	1931	D. Forbes	1934	Timekeeper, Kaiwiki Sugar Company, Ltd.*
June	1931	A. G. Hansen	1933	
June	1931	D. T. Silver	1933	Division Overseer, Kekaha Sugar Company, Ltd.
Aug.	1931	T. G. Eckart	1934	
Sept.	1931	R. P. Northwood	1933	
Oct.	1931	D. B. Thomson	1932	Acting Field Superintendent, Waialua Agricultural Company, Ltd.
Dec.	1931	S. W. Good, Jr.	1934	
Jan.	1932	R. C. Eckart	1935	
Mar.	1932	J. A. Swezey	1943	Head Luna, Waianae Plantation.
Mar.	1932	D. E. Larsen	1933	Manager, Kaiwiki Sugar Company, Ltd.
June	1932	L. W. Crosby	1933	
Sept.	1932	R. J. Borden		Agriculturist, Experiment Station, H.S.P.A.
Sept.	1932	A. D. Waterhouse	1935	Agriculturist, Maui Agricultural Company, Ltd.
Jan.	1933	W. S. Barnes	1935	Agriculturist, The Lihue Plantation Company, Ltd.
Feb.	1933	K. N. Hanks	1933	Office Manager, Waimanalo Sugar Company.
Mar.	1933	J. N. Schenck	1933	
Oct.	1933	D. S. Judd		Island Representative (Maui), Experiment Station, H.S.P.A.*
Oct.	1933	S. M. Miller	1935	Director of Labor Relations, H.S.P.A.
April	1934	F. A. Lyman	1936	Agriculturist, Pepeekeo Sugar Company.
June	1934	G. H. Douse	1936	
June	1934	A. K. Lyman	1936	
June	1934	C. C. Barnum	1935	
Aug.	1934	R. L. Walker	1935	Head Luna, Hakalau Plantation Company.

AGRICULTURISTS AND ASSISTANTS WHO HAVE SERVED IN THE AGRICULTURE DEPARTMENT AT THE EXPERIMENT STATION—Continued.

Appointed		Name	Services Terminated	Status of Those Who Remained with the Hawaiian Sugar Industry
Sept.	1934	J. W. Anderson	1937	Field Superintendent, Waialua Agricultural Company, Ltd.*
Mar.	1935	A. N. Walsh	1937	Office Manager, Laupahoehoe Sugar Company.
May	1935	K. H. Berg	1938	Division Overseer, The Lihue Plantation Company, Ltd.
June	1935	H. Frazier	1936	
Sept.	1935	W. P. Hodgins	1936	
Sept.	1935	W. J. Baldwin	1937	Division Overseer, The Lihue Plantation Company, Ltd.
Oct.	1935	R. A. Cushnie	1936	Harvesting Overseer, Ewa Plantation Company.
Mar.	1936	D. M. Hendricks	1938	
Mar.	1936	J. D. Thain	1937	
April	1936	C. E. S. Burns, Jr.	1937	Assistant Manager, McBryde Sugar Company, Ltd.
July	1936	W. C. Northrup	1938	
July	1936	L. R. Smith	1945	Administrative Assistant, Plantation Department, American Factors, Ltd.
July	1936	H. H. Hall	1937	Head Luna, Waiakea Mill Company.
July	1936	E. A. Johnstone	1937	
Aug.	1936	F. F. Hebert	1938	Section Overseer, The Koloa Sugar Company.
April	1937	R. D. Wheeler	1939	Section Overseer, Hawaiian Agricultural Company.
June	1937	E. C. Spillner	1939	Agriculturist, Grove Farm Company, Ltd.*
June	1937	J. Milne	1938	Assistant Agriculturist, Hawaiian Commercial & Sugar Company, Ltd.
June	1937	L. A. Thevenin	1938	Agriculturist, Honokaa Sugar Company.
July	1937	J. R. Garcia	1939	Agriculturist, Hakalau Plantation Company.
July	1937	J. K. Williams	1939	
Aug.	1937	A. L. Faye	1939	Section Overseer, The Koloa Sugar Company.
Sept.	1937	R. A. Cooke, Jr.	1939	Statistician, C. Brewer & Company, Ltd.*
Sept.	1937	P. I. Fagan, Jr.	1938	Agriculturist, Honolulu Plantation Company.
Jan.	1938	R. E. Jobes	1939	Section Overseer, Waialua Agricultural Company, Ltd.
April	1938	A. C. Stearns	1939	Agriculturist, Waialua Agricultural Company, Ltd.
July	1938	J. A. Verret, Jr.	1940	
July	1938	R. I. Knox	1940	Harvesting Overseer, Hutchinson Sugar Plantation Company.
Sept.	1938	C. R. Weight	1940	(Agriculturist, Onomea Sugar Company—Deceased October 18, 1944.)
Sept.	1938	R. L. Wold	1940	Agriculturist, Olokele Sugar Company, Ltd.
Oct.	1938	J. M. Crawford	1940	Agriculturist, Wailuku Sugar Company.*
Oct.	1938	R. A. Duncan	1940	Assistant Engineer, H.S.P.A.*
Nov.	1938	C. A. Wismer	1940	Agriculturist, Honokaa Sugar Company.*

AGRICULTURISTS AND ASSISTANTS WHO HAVE SERVED IN THE AGRICULTURE DEPARTMENT AT THE EXPERIMENT STATION—Continued.

Appointed		Name	Services Terminated	Status of Those Who Remained with the Hawaiian Sugar Industry
Feb.	1939	E. M. FAYE	1940	Section Overseer, Oahu Sugar Company, Ltd.*
July	1939	W. P. NAQUIN, JR.	1941	Special Assistant, Kohala Sugar Company.*
Sept.	1939	J. Z. KISSEN	1940	(Assistant-Agriculturist-In-Training—Experiment Station, H.S.P.A.—Deceased February 26, 1940.)
Oct.	1939	J. T. MOIR, III	1941	Assistant Agriculturist, Olaa Sugar Company, Ltd.*
Feb.	1940	D. H. BUTCHART	1941	
Feb.	1940	K. W. MCKENZIE	1941	Assistant Chemist, Experiment Station, H.S.P.A.*
June	1940	G. B. STEWART		Assistant-Agriculturist-In-Training—Experiment Station, H.S.P.A.*
July	1940	J. A. Johnson	1940	(Assistant-Agriculturist-In-Training—Experiment Station, H.S.P.A. Leave-of-Absence 1940 for National Guard, Killed in Action, Italy, January 25, 1944.)
June	1941	R. H. WARD		Assistant-Agriculturist-In-Training—Experiment Station, H.S.P.A.*
July	1941	J. N. WARNER		Assistant-Agriculturist-In-Training—Experiment Station, H.S.P.A.*
Dec.	1941	B. MCCALL	1942	Section Overseer, Paauhau Sugar Plantation Company.
June	1943	R. R. HIND, JR.	1943	
July	1945	H. A. ALEXANDER		Assistant-Agriculturist-In-Training—Experiment Station, H.S.P.A.

*In Armed Services or Defense Work

AVAILABLE
FOR REVIEWING

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 16, 1947, TO MARCH 15, 1948

Date	Per Pound	Per Ton
December 16, 1947—January 11, 1948	6.32¢	$ 126.40
January 12, 1948—January 13, 1948	5.70	114.00
January 14, 1948	5.65	113.00
January 15, 1948—January 20, 1948	5.60	112.00
January 21, 1948—January 26, 1948	5.65	113.00
January 27, 1948	5.649	112.98
January 28, 1948—February 3, 1948	5.57	111.40
February 4, 1948	5.50	110.00
February 5, 1948—February 12, 1948	5.45	109.00
February 13, 1948—February 16, 1948	5.50	110.00
February 17, 1948—February 25, 1948	5.55	111.00
February 26, 1948	5.45	109.00
February 27, 1948—March 3, 1948	5.50	110.00
March 4, 1948—March 15, 1948	5.45	109.00

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THE HAWAIIAN PLANTERS' RECORD

EXPERIMENT STATION STAFF

L. D. Baver, Director

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Table of Contents